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Physical Activity and Health-Related Quality of Life in Older Adults with Osteoporosis

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Physical activity and health-related quality of life
in older adults with osteoporosis
THESIS FOR DOCTORAL DEGREE (Ph.D.)

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*Not everything that can be counted counts,
and not everything that counts can be counted.*

ABSTRACT

An important part of the physical therapists' role is to help older adults to remain active as they age. Regular physical activity is essential for healthy aging and can delay functional decline and reduce the risk of premature mortality. This thesis comprise four studies, all including participants from the BETA-OP study, a randomized controlled trial (RCT), assessing the effects of a 12-week balance-training intervention for community-dwelling older adults, aged 65 years or over, with osteoporosis and fall-related concerns. The overall aim of the thesis was to explore correlates for physical activity in older adults with osteoporosis and to evaluate whether a specific, progressive balance-training program focusing on dual- and multi-task exercises for older had any short- and long-term effects on objectively measured habitual physical activity and health-related quality of life (HRQoL). The aim was also to compare self-reported pedometer steps with accelerometer-derived steps in older adults with osteoporosis, under free-living conditions.

Study I, a cross-sectional study (n=94), found that many older adults with osteoporosis are highly sedentary and a large proportion does not reach current health enhancing physical activity recommendations. A low daily step level, <5,000 steps per day, was associated with slower gait speed, poorer balance performance, lower HRQoL, and more sedentary time. Fall-related concerns were not associated with objectively assessed physical activity.

Study II included 71 older adults with osteoporosis and 73 with Parkinson's disease and found that both the Yamax LS2000 pedometer and the Actigraph GT1M/GT3X+ accelerometers can be used to assess steps per day in older adults with osteoporosis, but for individuals with altered gait pattern, accelerometers should be preferred.

Study III, a RCT with 61 participants in the intervention group and 30 in the control group, showed that the balance-training program had beneficial short-term effects on habitual physical activity. The odds ratio (95% CI) for having a daily step-count $\geq 5,000$ was 6.17 (1.23-30.91), $p=0.027$, for the intervention group compared to controls. The effect was not associated with improvements in gait speed, balance, or falls self-efficacy and did not persist through the long-term follow-up. No effect was found on HRQoL.

Study IV, was a qualitative study using inductive interpretive content analysis. Eighteen women were interviewed about perceptions and experiences of physical activity. We found that older women with a positive attitude to physical activity can manage to be physically active on their own if they feel secure about how much stress their bones can endure and which exercises are safe and suitable. Support and guidance from physical therapists, both individually and in group training, were important, but lack of advice from physicians about the benefits of physical activity on bone health was perceived as confusing.

In conclusion, these results indicate that a level of <5,000 steps/day can be associated with health risks and that objective assessment of physical activity is important to identify sedentary older adults with osteoporosis. The balance-training program had beneficial effects on habitual physical activity, but more support from physical therapists may be needed for sustained effects.

SAMMANFATTNING

En viktig del av fysioterapeutens roll är att stötta äldre personer till ett fysiskt aktivt åldrande. Regelbunden fysisk aktivitet ger betydande hälsovinster och kan minska risken för sjukdom, nedsättning av funktionsförmåga och för tidig död. Denna avhandling består av fyra studier, alla med deltagare från BETA-OP studien, en randomiserad kontrollerad studie (RCT) som utvärderar ett 12-veckors balansträningsprogram för personer över 65 år med benskrhet och ökad fallrisk. Det övergripande syftet med avhandlingen var att undersöka faktorer av betydelse för fysisk aktivitet hos äldre personer med benskrhet, samt att utvärdera om ett utmanande balanstränings-program med successivt stegrande svårighetsgrad och övningar där man gör flera saker samtidigt — dual- och multi-tasking — har kort- och långtidseffekter på objektivt mätt fysisk aktivitet och hälsorelaterad livskvalitet. Syftet var även att jämföra antal steg registrerade av en stegräknare (Yamax LS2000) med steg registrerade av en accelerometer (Actigraph GT1M/GT3X+) i dagliga livet.

Studie I var en tvärsnittsstudie med 94 äldre benskr personer, som visade att en stor del av deltagarna tillbringade mycket tid stillasittande och många nådde inte den rekommenderade dosen fysisk aktivitet. Personer som hade en aktivitetsnivå under 5000 steg/dag gick långsammare, hade sämre balans, lägre livskvalitet och var mer stillasittande. Graden av fallrelaterad oro hade inget samband med objektivt mätt fysisk aktivitet.

Studie II, som inkluderade 71 personer med benskrhet och 73 personer med Parkinsons sjukdom, fann att stegräknaren och accelerometern registrerade ett likvärdigt antal steg/dag hos personer med benskrhet, men att accelerometern är att föredra för att mäta steg hos personer med förändrat gångmönster.

Studie III var en RCT med 61 deltagare i interventionsgruppen och 30 i kontrollgruppen som visade att balansträningsprogrammet ledde till ökad fysisk aktivitet hos de minst aktiva. Odds ratio (95% CI) var 6,17 (1.23-30.91) för att ha en aktivitetsnivå över 5000 steg/dag för de som tränat balans jämfört med kontrollpersoner. Inga samband sågs mellan ökad fysisk aktivitetsnivå och förbättringar i gånghastighet, balans eller fallrelaterad oro. Inga säkra långtidseffekter kunde ses och inga effekter på hälsorelaterad livskvalitet kunde visas.

Studie IV var en kvalitativ studie med tolkande innehållsanalys som metod. Arton kvinnor intervjuades om sina uppfattningar och erfarenheter av fysisk aktivitet. Många av kvinnorna var fysiskt aktiva och upplevde sig som friska, trots sin benskrhetsdiagnos och fallrädsla. En positiv attityd till fysisk aktivitet och stöttning från fysioterapeuter främjade aktivitetsvanor, men avsaknad av råd från läkare om vikten av fysisk aktivitet vid benskrhet ledde till viss osäkerhet. Balansträningen gav ökad tro på den egna förmågan att vara fysiskt aktiv.

Sammanfattningsvis, en aktivitetsnivå under 5000 steg/dag kan vara förknippad med hälsorisker, och objektiva mätmetoder är viktiga för att identifiera stillasittande äldre personer med benskrhet. Balansträningen ökade den fysiska aktiviteten hos de minst aktiva, men stöttning från fysioterapeut kan behövas för att bibehålla en ökad aktivitetsnivå.

LIST OF SCIENTIFIC PAPERS

- I. Dohrn IM, Hagströmer M, Hellénus ML, Ståhle A.
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List of abbreviations

BETA	Balance elderly training activity
BMD	Bone mineral density
BMI	Body mass index
CI	Confidence interval
cpm	Counts per minute
DXA	Dual-energy X-ray absorptiometry
FES-I	Falls efficacy scale international
GEE	Generalized estimated equation
HRQoL	Health-related quality of life
ICC	Intraclass correlation
IQR	Interquartile range
LLDFI	Late life disability and function index
MCS	Mental component sum score
MET	Metabolic equivalent
MFE	Modified figure of eight test
MMSE	Mini-mental state examination
MVPA	Moderate-to-vigorous intensity physical activity
NW	Nordic walking (pole walking)
OLS	One leg standing test
OP	Osteoporosis
OR	Odds ratio
PCS	Physical component sum score
PD	Parkinson's disease
PROM	Patient-reported outcome measure
RCT	Randomized controlled trial
SD	Standard deviation
SF-36	Short-Form 36-item Health Survey

1 INTRODUCTION

Physical therapists are specialized in developing, maintaining and restoring people's ability to move and function throughout the lifespan. Through disease specific individually prescribed physical activity and exercise, physical therapists prevent and treat chronic conditions and disabilities. Regular physical activity can delay functional decline and reduce the risk of premature mortality, and an important part of the physical therapists' role is to help older adults to remain active as they age (1). A major goal of many physical therapy interventions for older adults is to keep individuals over the 'disability threshold' (Figure 1) (2). By being physically active, older adults can remain as healthy and independent as possible for the longest period of time, which has a great impact on the individual's quality of life, as well as the economic burden on society (2).

The physical therapy profession recognizes the use of evidence-based practice as central to providing high-quality interventions, by integrating clinical expertise with the best available evidence from systematic research (1). This requires both quantitative and qualitative scientific research and use of reliable and valid assessment methods. It is also necessary to investigate whether physical therapy interventions have effects beyond the end of the intervention. The studies included in this thesis strive to add to the broader knowledge of effects of physical therapy interventions and of factors of importance for physical activity and health-related quality of life (HRQoL) in older adults.

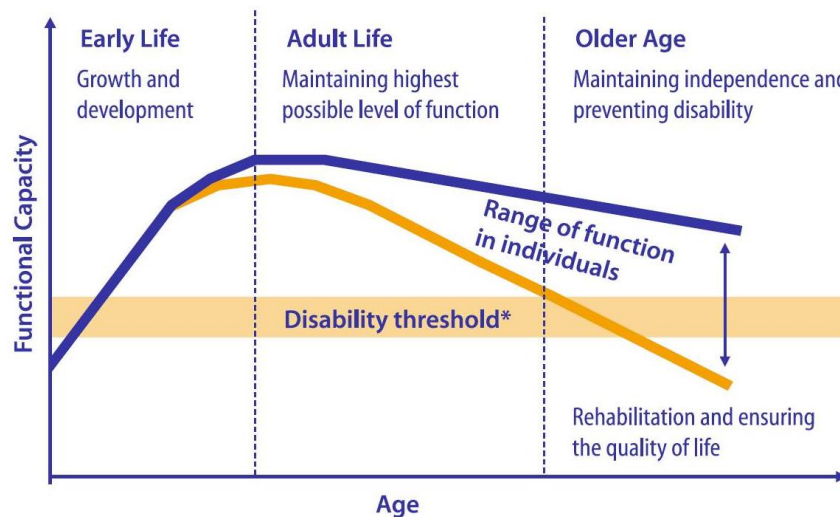


Figure 1. Functional capacities – i.e. respiratory capacity, muscular strength and cardiovascular performance – increase and peak during early adulthood and then decline with advancing age. The rate of decline is largely determined by factors related to adult lifestyle – such as smoking, alcohol consumption, levels of physical activity and diet – as well as external and environmental factors. The gradient of decline may become so steep as to result in premature disability. The acceleration in decline can be influenced and may be reversible at any age through individual and public policy measures. (Model by Kalache and Kickbusch, 1997).

Illustration and text reprinted from 'Active Ageing. A Policy Framework'. ©World Health Organization, 2002, used by permission.

This thesis comprise four studies, all including participants from the osteoporosis part of the BETA study (BETA-OP), a randomized controlled trial (RCT), assessing the effects of a 12-week balance-training intervention for community-dwelling individuals, aged 65 years or over, with osteoporosis and fall-related concerns (3). The BETA-OP study has previously been evaluated regarding the effects of the intervention on fall-related concerns, gait, balance performance and physical function (4). The overall aim of this thesis is to explore correlates for physical activity in older adults with osteoporosis and increased risk of falling, and to evaluate whether a specific and progressive balance-training program focusing on dual- and multi-task exercises for older adults has any short- and long-term effects on objectively measured habitual physical activity and HRQoL.

1.1 OLDER ADULTS

In this thesis, older adult refers to a person aged 65 years or over. Age classification has varied between countries and over time, and today there is no general agreement on the age at which a person becomes an older adult. The definition of an older adult can refer to different characteristics, such as chronological or biological age, or time of retirement. The United Nations has a cutoff at 60 years when referring to the older population (5), while the World Health Organization's (WHO) recommendations on physical activity for older adults targets individuals 65 years and older (6). Sweden and most western countries define persons aged 65 years and above as older adults (7). Since the 1990's, the average life expectancy has increased for both women and men in Sweden; in 2013, the life expectancy for women was 84 years and 80 years for men (7). With increasing longevity worldwide, population statistics or research studies sometimes define the oldest old as a separate group, generally those over 80 or 85 years. In 2013, was 19 percent of the population in Sweden 65 years or older (8).

1.2 PHYSICAL ACTIVITY

Physical activity is an umbrella term defined by Caspersen and colleagues (9) as “any bodily movement produced by skeletal muscles that results in energy expenditure” above the basal resting level. Physical activity comprises all activities of daily living, commonly described by the domains in which the activity occurs: domestic, occupational, transportation, and leisure time (10). The term habitual physical activity refers to all activities a person does as part of their regular daily life. Exercise is a sub-category of physical activity that is planned, structured, and repetitive with the purpose to improve or maintain physical fitness, such as cardiorespiratory fitness, muscle strength, flexibility or balance performance, and may be performed for pleasure or to maintain health (9).

1.2.1 Dimensions of physical activity

Habitual physical activity can be described in four principal dimensions: type, frequency, duration and intensity (10-12). Type refers to the specific activity performed — for example walking, cycling or gardening. Type can also be defined in the context of physiological and biomechanical demands, such as aerobic versus anaerobic activity, strength training or balance-training. The total volume of habitual physical activity is the product of frequency x

duration x intensity. Frequency refers to the number of activity sessions per time period (e.g. a day or a week) and duration refers to the time spent in the activity each session. Intensity describes the energy expenditure, or estimated effort, associated with the activity and can be expressed in absolute or relative terms. Absolute intensity is commonly quantified by determining the energy expenditure in kilocalories or by using the metabolic equivalent (MET) of the activity. One MET corresponds to the resting energy expenditure during quiet sitting for a standard 70 kg person, approximately 3.5 ml O₂/kg/min (or 1 kcal/kg/ h) (11, 12). Absolute intensity can also be quantified by body movement, such as stepping rate or three-dimensional body accelerations. Relative intensity refers to a value relative to peak performance and takes the individual's age or fitness level into consideration. It can be described as percentage of maximum aerobic capacity (VO_{2max}) or maximum heart rate (11), or by perceptual characteristics, such as rating of perceived exertion (13).

1.2.2 Physical activity and health

The health benefits of physical activity and exercise have been known since ancient times; traditional Chinese medicine has used exercises to enhance health since the 25th century BC. The importance of fitness and a physically active lifestyle was also emphasized in ancient Greece (14). A quote attributed to Hippocrates states, “eating alone will not keep a man well, he must also take exercise [...] to produce health” (15). However, vigorous exercising and severe exertion were believed to be harmful, a view that persisted into the 19th century. The importance of both active and passive exercises for rehabilitation was documented in Europe in the late 18th century, and William Buchan, a Scottish physician, suggested that “exercise alone would prevent many of those diseases which cannot be cured, and would remove others where medicine proves ineffectual”(15). When the physical therapy profession evolved in Sweden during the 19th century, patients with a diversity of diseases and symptoms were treated by physical therapists using individually prescribed exercises in addition to manual therapy (16).

The epidemiological work by Morris and colleagues (17) in the 1950's is considered to be a landmark of modern physical activity research. Their study of London transport workers found that conductors on the double-decker buses who were physically active had lower coronary heart disease rates than the sedentary bus drivers, and the same result was found in postal delivery workers, as opposed to less active clerks. Paffenbarger and colleagues (18) further established the association between a physically active lifestyle and health in men in the Harvard Alumni Health Study in the 1970's, and later the Nurses' Health Study has shown similar effects in women (19). Research in the following decades has provided strong evidence for the associations between habitual physical activity, both aerobic and muscle-strengthening activities, and all-cause mortality or chronic diseases, such as cardiovascular disease, stroke, type 2 diabetes, obesity, osteoporosis, colon cancer, breast cancer, and depression (6, 20).

The first public health recommendations on physical activity were issued 1995 by the Centers for Disease Control and Prevention and the American College of Sports Medicine (ACSM) in

a consensus statement establishing the dose-response relationship between physical activity and health (21). The dose-response relation implies that the largest health benefits will occur if those who are inactive or very low active become somewhat active, and that longer duration or higher intensity of the physical activity will give additional health benefits. The exact shape of the dose-response curve is still unclear and may vary depending on population, type of activity, health outcome and baseline activity level (22, 23). An update of the recommendations was published in 2007, based on numerous cross-sectional and epidemiological studies and RCTs, providing a deeper understanding of the mechanisms behind the health benefits of physical activity, and of the activity volume associated with enhanced health and HRQoL (22).

1.2.3 Physical activity recommendations for older adults

Healthy adults aged 65 years and above, are recommended to do at least 150 minutes of moderate intensity aerobic activity (i.e., brisk walking) per week or 75 minutes of vigorous intensity aerobic activity (i.e., jogging or running) per week, or an equivalent combination. The aerobic activity should be performed in bouts of at least 10 minutes. In addition, muscle-strengthening activities for major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms) are recommended on two or more days per week (6, 20, 24). Older adults with impaired balance or poor mobility are also recommended to perform physical activity at least three days a week to enhance balance and prevent falls (6, 20, 24). (Figure 2) The dose-response relationship between physical activity and health indicates that additional health benefits can be achieved if more time is spent in aerobic physical activity.

The recommendations for healthy older adults are also relevant to older adults with chronic conditions or with disabilities. Some activity is better than none, and those who cannot reach the recommended amounts of physical activity due to health conditions should be as physically active as their abilities and conditions allow (6).

1.2.4 Step defined recommendations

To accurately recall time spent in different activities or estimate activity intensity might be difficult, especially for older adults, who often have a more sporadic physical activity pattern than younger people. An alternative strategy to recommendations based on time and activity intensity, is to encourage people to achieve a daily step count (25). Step count is a simple and straightforward method of assessing physical activity behavior proven to be valid and sufficient for capturing habitual physical activity volume (26). A number of studies have shown that step count interventions are successful in increasing habitual physical activity (27, 28). A goal of 10,000 steps per day is often cited as a recommended target for health, but even fewer steps may meet the current health recommendations. According to Tudor-Locke and colleagues' translation of 150 minutes of moderate-to-vigorous physical activity (MVPA) into steps per day, healthy older adults are recommended to achieve at least 7,100 steps per day, if averaged over a week (25). This has been adopted in ACSM's recommendations for exercise prescription (29), although the appropriateness of this recommendation remains to be

proven. It is estimated that a minimum level of 4,600 step per day, if averaged over a week, is needed to include 150 minutes of MVPA for older adults with or chronic conditions or disabilities.

An activity level of less than 5,000 steps per day is generally considered to be very low, and it is suggested as an indicator of a 'sedentary lifestyle' (Figure 2) (30). This threshold has been applied in a limited number of studies, showing that individuals taking less than 5,000 steps per day are more likely to have reduced HRQoL and higher prevalence of cardiovascular risk factors, obesity, and depression, but further evaluations are needed (30). A habitual level of 5,000 steps or more per day has been associated with normal bone mineral density (BMD) in normal-weight women (31).

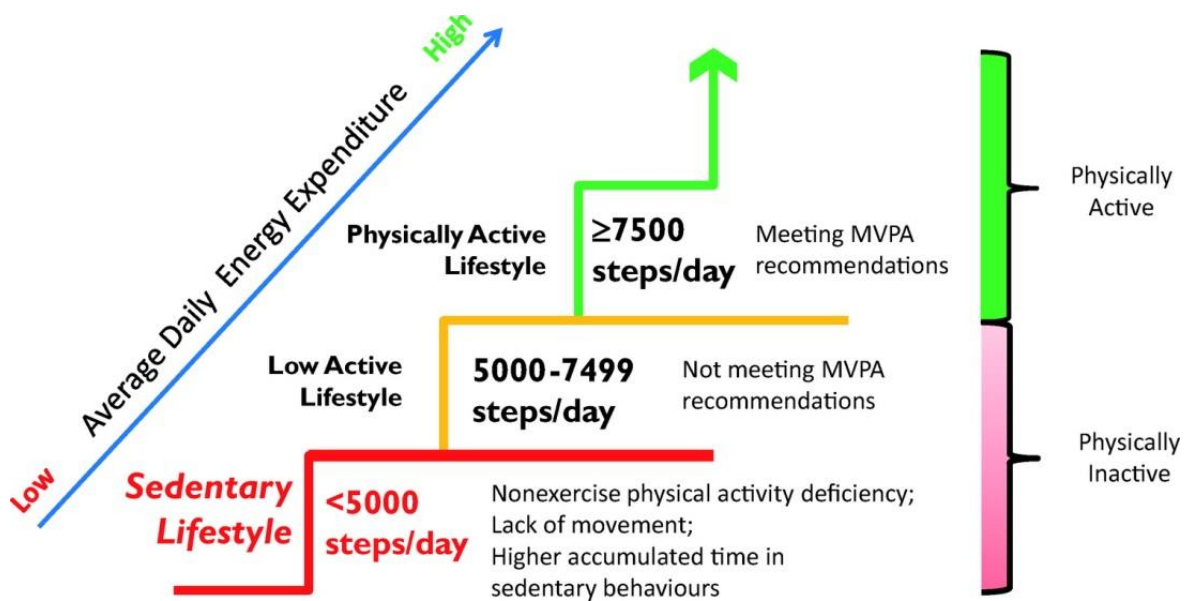


Figure 2. Tudor-Locke et al. have proposed that a level of <5,000 steps per day should be considered as a sedentary lifestyle. The concept strives to answer the question 'How many steps/day are too few?' and this schematic explanation of the concept was published in a review article in Appl. Physiol. Nutr. Metab. 2013;38:100–114. © Canadian Science Publishing or its licensors, used by permission.

1.2.5 Physical activity in older adults

Physical activity is a dynamic and complex behavior and many factors: individual, social, and environmental, influence habitual physical activity (32, 33). Generally, physical activity levels are lower with higher age and a substantial number of older adults do not engage in sufficient physical activity (Figure 3). Only 20-60 percent of older adults meet the recommendations, depending on assessment method and definition of the recommendation (34-36). Most studies have been conducted on healthy older adults, a very heterogeneous population, and normative step values therefore span a wide range: 2,000-9,000 steps per day (25). Many studies report that older women have lower physical activity levels, spend less time in high intensity activities, and are less likely to meet physical activity recommendations compared to older men. These gender differences are predominantly found in self-reported data, suggesting that this may depend on how physical activity is assessed.

Correlates and determinants of physical activity are well studied in children, adolescents and adults, but less are explored in older adults — especially older adults with chronic conditions (32). Frequently reported reasons to be physically active among older adults are social interaction, accessible facilities, physician encouragement, as well as purposeful and enjoyable activities. Beliefs in the benefits of exercise, outcome expectations, and exercise self-efficacy are also factors associated with exercise activities (33, 37). Fall-related concerns, fear of injury, and mobility limitations are known barriers to physical activity in older people, although health concerns have been reported as both a motivator for and a barrier to physical activity (32, 37, 38).

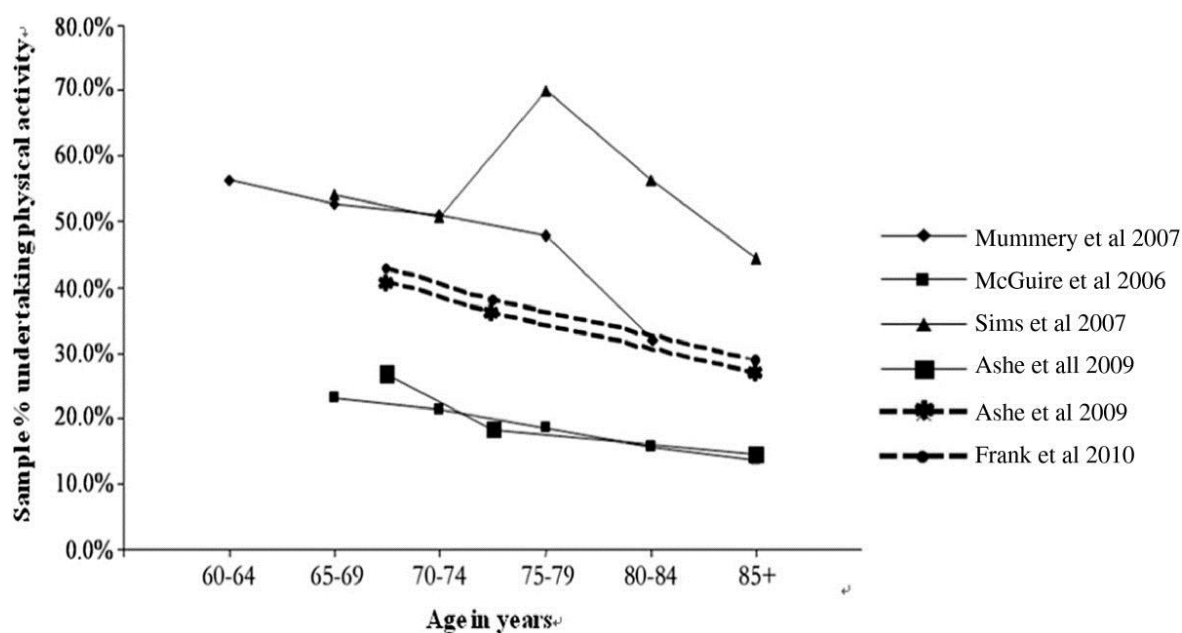


Figure 3. Physical activity prevalence across age groups. Sun et al. Physical activity in older people: a systematic review. BMC Public Health. 2013; 13:449. © 2013 Sun et al.; licensee BioMed Central Ltd, used by permission.

1.2.6 Sedentary behavior

Sedentary behavior is defined as any waking behavior characterized by very little body movement and an energy expenditure ≤ 1.5 METs, often with the addition: in a sitting or reclining posture (39, 40). It has been proposed as an independent risk factor for poor health in ageing and has been associated with obesity, type 2 diabetes, cardiovascular disease, specific cancers and all-cause mortality, independent of time spent in MVPA (41, 42). Both total time spent sedentary and prolonged time sedentary without breaks have been associated with health risks (43, 44). Still, sedentary behavior is a fairly new research area and more studies are needed. Current evidence is insufficient for specific recommendations on maximum sedentary time per day or week, or breaks in sedentary time. However, advice on reducing sedentary time and increase light intensity physical activity or MVPA is in accordance with physical activity recommendations for older adults, stating that ‘some activity is better than none’ (6).

High volumes of sedentary time have been observed among older adults (45), but there is only limited knowledge of the potential impact of sedentary time on physical function. A recent study found that television viewing time was prospectively associated with slower gait speed in community-dwelling older adults (46) and another prospective study reported that sedentary time was strongly associated with decreased physical function, most pronounced among older women and those reporting the most sedentary time (47). Few studies have used objective assessment of sedentary time in older adults. However, two recent studies found objectively assessed sedentary behavior to be associated with lower BMD of the femur region in women (48) and higher predicted cardiovascular risk in older adults with mobility limitations (49).

Sedentary behavior is sometimes used interchangeable with the term ‘inactivity’ and there is no uniform definition of physical inactivity, but ‘inactive’ is suggested as a term for describing a person who does not meet physical activity recommendations (50).

1.3 ASSESSMENT OF PHYSICAL ACTIVITY

Physical activity can be assessed as either the energy cost of the body movement (energy expenditure) or as the movement behavior. Depending on how data are collected, physical activity assessments methods can also be categorized as either subjective or objective.

1.3.1 Subjective methods

Subjective methods for assessment of physical activity rely on the individual either to record activities as they occur or to recall previous activities and comprise self-administered questionnaires, activity diaries, and interviews. Most frequently used are questionnaires, especially in epidemiological studies, given that they are relatively easy to administer at a low cost. Questionnaires vary in detail, from short global instruments with a few items to give an overview of activity level, to long, detailed quantitative questionnaires covering the history of activity over the past year or even a lifetime (11, 12). Questionnaires are often used to

classify individuals as ‘active’ (i.e., meeting physical activity recommendations) or ‘inactive’. Activity diaries can provide detailed hour-by-hour information, but entail a high participant burden and may also affect physical activity behavior. Both questionnaires and activity diaries can be used for more detailed calculations of energy expenditure, using standard energy costs of specific activities (METs), even though the validity is low due to large individual differences in energy costs for the same activity. Interviewer-administered questionnaires have a higher validity and are also preferred for more detailed assessments of activity behavior (11). In-depth interviews are valuable for providing a deeper understanding of physical activity behaviors, such as attitudes to physical activity or exercise, perceptions and experiences of physical activity, or of physical activity correlates (51).

A disadvantage with subjective assessments is the low accuracy for determining physical activity volume. Self-report methods often overestimate actual activity volume due to recall bias and social desirability bias (i.e., tendency to report physical activity levels corresponding to perceived expectations). However, certain activities may also be underestimated, especially unstructured activity interspersed over the day, and light intensity activity — both common behaviors among older adults (52). In addition, wording and definitions in questionnaires may introduce bias. For example, household activities, which in many cases are activities specific to older women, are sometimes excluded in questionnaires about leisure time physical activity used for comparison to the criterion of sufficient physical activity (35).

1.3.2 Objective methods

Objective methods are generally more accurate than subjective methods and involve both specific assessment of energy expenditure and assessment of actual movement behavior (11). Doubly labelled water method and direct calorimetry are two accurate, but expensive, methods measuring energy expenditure mainly used for validation research. Indirect calorimetry, employing portable devices, is a more accessible method for assessment of energy expenditure by measuring ventilatory volume and oxygen uptake. Direct observation is another method primarily used as a validation criterion, but it can also generate important contextual information about physical activity behavior, such as mode of physical activity, as well as when, where, and with whom it occurs. The substantial investigator burden and invasion of participant privacy limit the applicability of direct observation in free-living conditions, and it has mainly been used when studying children (11, 12).

1.3.2.1 Wearable movement sensors

The most frequently used objective methods for assessing physical activity behavior are pedometers and accelerometers, both small wearable movement sensors.

Pedometers measure ambulatory activity, such as walking and stepping, and basically provide information on number of steps taken. The internal mechanisms for detecting steps in pedometers are either a spring-suspended lever arm, a horizontal beam, or a piezoelectric crystal (similar to the mechanism in accelerometers) (12). Pedometers commonly used in research, such as Yamax and Omron, are valid instruments for assessing walking behavior,

which is the most frequent physical activity in older adults; although, the accuracy can be attenuated at very slow walking speed and in individuals with an altered walking pattern (12, 53). While not ideally suited for assessing physical activity pattern or intensity of activity, pedometers have several advantages, such as low cost, low participant burden, ease of use, and having an output (i.e., steps) that is easy to understand (54).

Accelerometers record changes in velocity over time in one or three axis. The raw data, expressed as units of acceleration due to gravity (g) in m/s^2 , are transformed into ‘activity counts’, from which frequency, duration and intensity of physical activity can be calculated (12, 53). The processing of raw accelerometry data into activity counts is brand-specific and different filter settings are used for eliminating ‘noise’ (i.e. signals outside the range of human movement). Cut-points, or thresholds, for the activity counts are determined from calibration studies to classify activity intensity (55). Cut-points are brand specific and may vary across different populations. A wide range of cut-points has been suggested to define MVPA for community-dwelling older adults (56-58) and it remains unclear if there is an optimal cut-point (58).

Even though much scientific work has been conducted in the recent years to develop pattern recognition in accelerometers (55), they can only provide limited information about type of activity. The increased interest in sedentary behaviors has put focus especially on evolution of functions to differentiate sitting from standing, but the accuracy in many brands is still not sufficient. One type of pattern recognition most accelerometers have is a step count function, however, differences in mechanisms and in instrument sensitivity thresholds between pedometers and accelerometers suggest that step data derived from the two types of sensors may not be used interchangeably, and this need to be further investigated (59). Other limitations are that the current measurement mechanisms in most sensors are unsuitable for measurement of swimming or cycling, and they cannot account for the additional energy expended in activities such as stair climbing, uphill walking, or carrying loads (12, 53).

1.4 HEALTH-RELATED QUALITY OF LIFE

1.4.1 Concept of health-related quality of life (HRQoL)

Health-related quality of life (HRQoL) is a multidimensional concept focusing on how health status and treatment affects individuals’ quality of life. Health-related quality of life encompasses aspects of both physical and mental health, as well as emotional and social well-being (60). A conceptual model of HRQoL was developed in 1995 by Wilson and Cleary (61) to clarify the elements of HRQoL and their relationships, and this model was later revised by Ferrans and colleagues in 2005 (Figure 4) (62). An important aspect of HRQoL is that it is a patient-reported outcome measure (PROM), and thereby an important complement to clinical endpoints for evaluating effects of different interventions, both in research as well as in clinical practice (63).

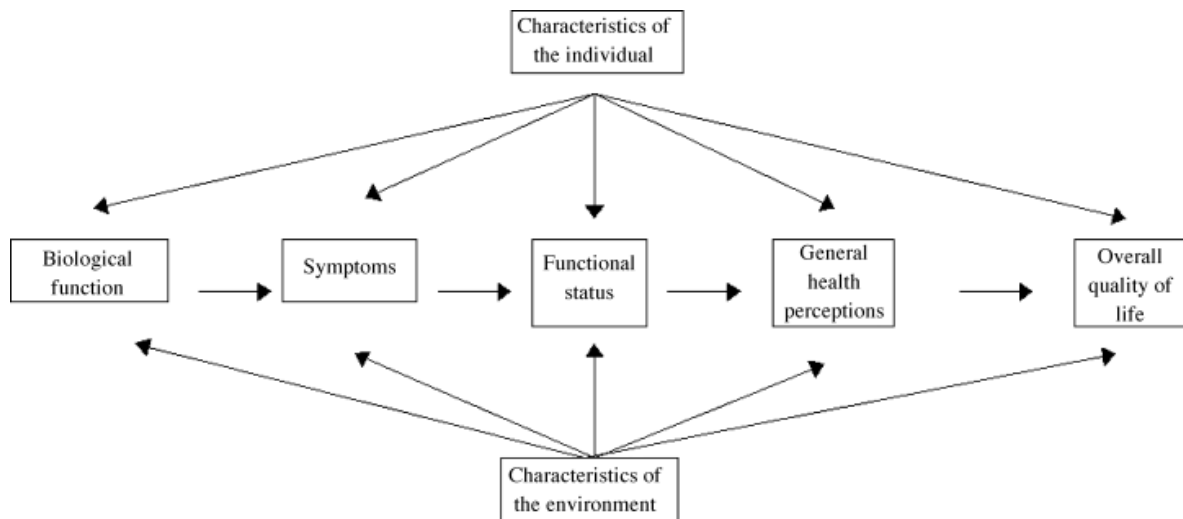


Figure 4. Revised conceptual model for health-related quality of life by Ferrans et al. 2005. The arrows indicate the dominant causal associations. Reciprocal relationships might exist, but are not characterized in the figure. ©Journal of Nursing Scholarship, used by permission.

1.4.1.1 HRQoL versus ICF

The International Classification of Functioning, Disability, and Health (ICF) is an adjacent framework designed by the WHO for describing and organizing health information on function and disability (64). In ICF, disability and functioning are viewed as outcomes of interactions between health conditions and contextual factors, and disability involves dysfunction at one or more of three levels: impairments, activity limitations and participation restrictions. The ICF model is often used in physical therapy research and is a suitable tool for mapping and classification when studying health-status and disability. However, the ICF does not specifically measure HRQoL and Ferrans and colleagues' model is therefore recommended for HRQoL research and practice (65).

1.4.2 Assessment of HRQoL

The purpose of HRQoL assessments is to quantify the degree to which a medical condition or its treatment affects the individual's life in a valid and reproducible way. Several self- or interviewer-administered HRQoL questionnaires have been developed with two basic approaches: generic instruments, or specific instruments focusing on concerns related to specific diseases, patient groups, or areas of function (60). Older adults typically report poorer physical health than the younger population (66) and measuring HRQoL from the perspective of an older person may have to meet specific challenges and needs. A review focusing on evaluating generic HRQoL measurement in older people found that the Short-Form 36-item Health Survey (SF-36), a widely used generic health profile, had good evidence of responsiveness across a range of settings and populations suggesting that it is sensitive to change, particularly in community dwelling populations and in those with lower levels of morbidity (67). The SF-36 covers eight domains: physical functioning, role-physical, bodily pain, general health perceptions, vitality, social functioning, role-emotional, and mental health.

1.4.3 Relationship between physical activity and HRQoL

Cross-sectional studies have shown moderate to strong associations between physical activity and HRQoL in the general adult population, with some support for a dose–response relationship (68); although, associations based on cohort studies and RCTs, are weaker (68). The association between physical activity and HRQoL in older adults is moderately positive, but sometimes mixed, and the influence of physical activity may vary in different domains of HRQoL. It is not possible to conclude whether there is a causal pathway between higher levels of physical activity and higher levels of HRQoL in older adults, or vice versa. Other factors, such as self-efficacy, may mediate the association between physical activity level and HRQoL (68). Further, most studies rely on subjective assessment of physical activity, and self-reported physical activity and HRQoL may have conceptual overlaps, especially in the physical functioning domains of HRQoL, inflating the actual relationship between these two constructs (68).

1.5 OSTEOPOROSIS

Osteoporosis is a systemic skeletal disease characterized by low bone mass due to micro architectural deterioration of bone tissue. The consequent bone fragility with increased risk of fractures is the main clinical consequence of the disease (69). Osteoporosis is diagnosed by BMD assessment by dual X-ray absorptiometry (DXA scan) at the spine or hip. According to the WHO criteria is osteoporosis defined as a BMD value 2.5 standard deviations (SD) or more below the average value for young healthy women (70). Osteoporosis primarily affects older people and the prevalence increases markedly with age. It is estimated that six percent of women aged 50–54 years have osteoporosis, and among women over 80 years almost 50 percent have a BMD value in the osteoporosis range (71). Over 200 million people worldwide have osteoporosis (72), although the actual prevalence may be even higher since osteoporosis is a silent disease without specific symptoms and it is usually not be detected until a fracture occurs.

Due to an increasing population of older adults are osteoporosis-related fragility fractures a major public health concern today and for the foreseeable future. Osteoporosis causes nine million fractures annually worldwide and more than one-third occur in Europe. At the age of 50 years, the remaining lifetime probability for a fragility fractures is 46 percent in women and 22 percent in men (71). The most common osteoporosis-related fractures are those at the hip, spine, distal forearm and proximal humerus. Fragility fractures are associated with substantial pain and suffering, disability and even death for the affected individuals, and the related costs to society are substantial (71).

1.5.1 Prevalence and costs for osteoporosis in Sweden

Osteoporosis is common in Sweden and the number of individuals with osteoporosis was estimated to be 520,000 in 2010 (73). The number of incident fractures was estimated at 107,000, and 66 percent of those occurred in women. Causally related deaths during the first year after a fracture were 1,170 in 2010, with hip fractures accounting for about 50 percent of

deaths (73). The cost of osteoporosis in Sweden was estimated at € 1,486 million in 2010, including acute fracture costs, long-term disability costs (i.e., nursing home care) and fracture prevention costs (mainly costs for drug treatment). When the cost of osteoporosis was combined with quality adjusted life years (QALYs) lost due to osteoporosis, the total amount was € 4.2 billion. The cost is expected to increase to € 5 billion by 2025 (73).

1.5.2 Physical activity as prevention and treatment of osteoporosis

Convincing evidence indicates that regular weight-bearing physical activity has beneficial effects on bone health across the age spectrum. Activities that generate relatively high-intensity loading forces, such as jumping, jogging, aerobics, or strength training, increase BMD in youth and thereby help to maintain bone health in later life (20, 74). Both gravity force and dynamic mechanical strain from muscles are needed to enhance BMD and, consequently, activities like and cycling and swimming have less impact on bone health (20, 74). Bone mass decreases by about approximately 0.5 percent per year or more after the age of 40, regardless of sex or ethnicity. In women, the estrogen withdrawal at menopause results in rapid BMD loss that is distinct from the slower age-related loss (74). The rate of BMD loss also depends on genetics, nutrition, and habitual physical activity. There is convincing evidence for small, but important, effects of strength training on BMD in postmenopausal women and, importantly, exercise can also improve muscle mass, strength, coordination and balance, and thereby protect against both falls and fractures (75).

Promotion of physical activity is considered a golden rule of osteoporosis treatment, in addition to fall prevention, nutrition supplements and pharmacologic therapy (76, 77). Individuals with osteoporosis are recommended to engage in strength training in combination with other weight-bearing activity to constrain bone loss and increase BMD (20), but firm evidence is lacking about the optimal dose of physical activity for individuals with osteoporosis. Most studies on the effects of physical activity on osteoporosis have been conducted in women, but it appears that the bones respond similarly in both sexes. A prospective study showed a 60 percent reduction in hip-fracture rates in physically active men compared to inactive men (78), and associations between objectively measured MVPA and BMD in the hip and tibia have been found both in 70-year-old men and women (79). A recent expert consensus statement (80) about physical activity and exercise recommendations for adults with osteoporosis, with or without vertebral fractures, recommends the following:

- current physical activity recommendations are appropriate for individuals with osteoporosis without spine fracture
- after spine fracture, physical activity of moderate intensity is preferred to vigorous
- daily balance-training and endurance training for spinal extensor muscles are recommended for all
- specific spine-sparing techniques are recommended rather than providing generic restrictions about lifting and twisting
- in the presence of pain, multiple fractures or hyperkyphosis, consultation with a physical therapist is recommended to ensure safe and appropriate exercise

1.5.3 HRQoL in persons with osteoporosis

Individuals with chronic diseases generally present lower (worse) HRQoL profiles than healthy persons do. Studies on individuals with osteoporosis have found associations between lower HRQoL scores and osteoporotic fractures (81, 82). Specifically, postmenopausal women with vertebral fractures have reported poorer physical and mental health, as well as more role limitation (physical and emotional) and pain, than those without vertebral fractures or healthy controls (82). Hip or multiple vertebral fractures have a considerably greater and more prolonged impact on HRQoL than humerus or distal radius fractures, or a single vertebral fracture (81). Data on HRQoL in patients with osteoporosis without vertebral fractures are limited and variable, but suggest that HRQoL is adversely affected by osteoporosis even in the absence of vertebral fractures (83). The lower HRQoL may originate from the increased fracture risk, fall-related concerns, or fear of future loss of independence.

Beneficial effects of exercise interventions on HRQoL in older women with osteoporosis have been suggested, although the body of evidence regarding associations between physical activity and HRQoL in older adults with osteoporosis is still limited (84).

1.6 FALL-RELATED CONCERNS

In this thesis the term fall-related concerns is used as a general, common concept for fear of falling, fall-related self-efficacy, balance confidence, and concerns about falling as previously suggested by Halvarsson (85).

Falls are a significant cause of morbidity and premature mortality among older people and approximately one third of community-dwelling older adults fall each year (86, 87). Fall-related concerns are common, also among those who have not experienced any falls or related injuries; the prevalence is estimated to be 21-85 percent (86). Both a previous fall and fall-related concerns increase the risk of falling (86). Traditionally, fall-related concerns are considered to lead to self-imposed physical activity restriction, formulating a vicious circle: fall-related concerns → activity avoidance → muscle decline → impaired balance performance → falls, leading towards frailty and decreased independence, and consequently reduced HRQoL (86, 88-90). This fear-avoidance model was one of the fundamental assumptions when the hypothesis of this thesis was formulated in 2010, but later research has questioned this model. Hadjistavropoulos and colleagues (89) have suggested that activity avoidance/physical inactivity is not necessary as a key central mediator. Their alternative explanation is instead: fear and anxiety → impaired balance performance → falls, and propose that this conceptualization could guide future research and call for more studies with clinical focus (89).

A Cochrane review has found that exercise interventions can reduce fall-related concerns in community-dwelling older adults (86). The evaluated trials investigated individual exercise programs, exercise prescription, and group training interventions, including balance-training and/or strength training, and Tai Chi or yoga. There were not enough evidence to conclude if the effect differed between different types of interventions, or to determine whether the

interventions reduced fall-related concerns beyond the end of the interventions. The authors conclude that more RCTs with long-term follow-up are needed.

1.7 PHYSICAL FUNCTION IN OLDER ADULTS

Ageing is associated with decline in most physiological systems (i.e. cardiorespiratory, musculoskeletal, sensory) and subsequent decreased physical function. This age-related decline was previously considered inevitable, but research has shown that much of the decline in physical functions are instead related to physical inactivity and ‘disuse’ (52). This is of great importance, since the decline attributed to disuse can be attenuated or reversed by exercise, and prolongs the time to the disability threshold, and even death (52).

1.7.1 Role of physical activity in preserving function

Physical activity and exercise can help prevent function loss and disability during aging by a variety of mechanisms, directly and indirectly (52, 91). Physical activity can modify risk factors for common chronic and disabling diseases (e.g. cardiovascular disease, type 2 diabetes etc.) and influence other contributors to disability, such as depression and low self-efficacy. The course or consequences of diseases that are already present can be altered by physical activity and exercise. A physically active lifestyle can also limit age-related loss of muscle mass and muscle function, i.e. sarcopenia (92). Strength training is important for preserving muscle mass and maintaining lower extremity function, necessary for balance performance and gait speed. Physical function measures, like grip strength, gait speed, and balance performance can predict all-cause mortality, cardiovascular disease, fractures, sarcopenia, loss of independence and hospitalization in older community-dwelling populations (92-94).

1.7.2 Balance control

Balance control is a multifaceted function and the ability to stand, walk and perform daily activities in a safe manner depends on a complex interaction of several physiological systems: musculoskeletal, neuromuscular, vestibular, somatosensory and visual (95). Balance control declines with age due to natural degenerative processes or pathological processes in these systems. Decreased flexibility in the spine or hyperkyphotic posture, as consequences of multiple vertebral fractures, may reduce balance control and thereby modify fall risk or the effect of exercise on fall risk in individuals with osteoporosis (77).

Balance control requires many cognitive resources, and the more difficult the postural task, the more cognitive processing is required (96). Balance control and other cognitive processes share cognitive resources, and central changes in the aged brain reduce dual-tasking, i.e., ability to perform a motor task while simultaneously engaging in a cognitively demanding task. Dual-task conditions affect balance control, and thereby gait and fall risk, in both healthy and balance-impaired older adults (96, 97).

In this thesis, the term balance performance is used for assessments and evaluation of balance control.

1.7.3 Gait speed

Walking is the most common type of physical activity in older adults and many health benefits can be gained through regular walking (33). Walking requires energy, movement control, and support from multiple organ systems, including the heart, lungs, circulatory, nervous, and musculoskeletal systems (98). Ability to walk at different speeds and to modify gait in response to changing demands, such as on different surfaces and in varying environments is necessary to meet the everyday challenges (99). Age-related decline in functional and physiological capacity reduces gait speed, and habitual gait speed has been shown to reflect health status and be associated with survival rates among older adults (100). Gait speed is also correlated with fall-related concerns and falls (98). It is suggested that a gait speeds faster than 1.0 m/s is associated with healthy aging, while gait speeds slower than 0.6 m/s increase the likelihood of poor health and function. Studenski and colleagues found that a gait speed of 0.8 m/s predicted average life expectancy for older community-dwelling adults (100).

Self-selected gait speed is an objective measure useful for physical therapy interventions, both as a predictor and an outcome variable. Measurements of gait speed are highly reliable, regardless of the method for measurement, for different patient populations and for individuals with known impairments affecting gait (98, 99). Systematic research has found that exercise interventions can have beneficial effects on gait speed in older adults (101).

1.8 PHYSICAL THERAPY EXERCISE INTERVENTIONS

According to a policy statement by World Confederation for Physical Therapy (WCPT), is physical therapy concerned with identifying and maximizing quality of life and movement potential within the spheres of promotion, prevention, treatment/intervention, habilitation and rehabilitation (1). Physical therapy practice includes health promotion by emphasizing the importance of physical activity and exercise, both for the individual and for the general public/society (1). Exercise is a principal component of physical therapy interventions, aiming to optimize the individuals' ability to be physically active, and thereby enhance HRQoL and reduce functional decline or disability.

Although there are inconsistencies in results from RCTs regarding the benefits of exercise on disability, there is evidence from prospective studies that physical activity has a protective effect (102). There is clear and convincing evidence that late-life exercise has important positive effects on physiological parameters as well as on basic physical function (103). Systematic research has shown that exercise interventions have beneficial effects on strength, aerobic capacity, and flexibility both in healthy older adults and older adults with chronic conditions/disability. Older adults who engage in strengthening and aerobic exercise also improve their balance, walking, and transfer activities (102). There is also consistent scientific evidence that physical therapy programs can improve physical functions, such as balance and gait speed in older adults. A regular multicomponent exercise program is the most effective physical therapy approach for the prevention of falls and fractures in

community-dwelling older adults (104, 105). It remains unclear, however, if interventions that improve physical functions also have beneficial effects on HRQoL due to inconsistent research findings (105, 106).

There is a lack of studies evaluating if physical therapy programs without specific physical activity promotion are enough to stimulate older adults to become more active on their own. Only a small number of studies have evaluated the effect of exercise interventions on physical activity. A meta-analysis of physical therapy RCTs aiming to improve physical function in community-dwelling older adults found positive effects on mobility and physical functioning, but no effect on physical activity (106). The few included studies used subjective assessment of physical activity, which highlights the need for more research, especially studies using objective methods.

Studies with follow-up measurement on the effect of exercise past the end of the intervention are scarce and it is suggested that the benefits are short-lived when exercise is discontinued (101, 106). Nevertheless, significant effects on gait speed and balance up to one year after discontinuing exercise have been found in a small number of studies (101, 107). More evidence is needed to test the sustainability over time of the effects of physical activity interventions.

1.8.1 Balance-training

To be successful, all types of training, including balance exercises, need to be individually adjusted, specific, and performed at or near the limits of one's capacity (29). A Cochrane review from 2012 (108) evaluating exercise for improving balance in older adults found that gait, balance, co-ordination, and functional tasks exercises, as well as strengthening exercise and multicomponent exercise programs were moderately effective in improving balance performance immediately after intervention. The evidence was insufficient to draw any conclusions for general physical activity (i.e. walking or cycling), and studies with long-term follow were scarce (108). Another review found convincing evidence that it is necessary to incorporate dual-task exercises in balance-training interventions to improve dual-task performance (109). Both reviews concluded that studies evaluating balance-training with long-term follow-up is lacking (108, 109).

Halvarsson and colleagues have previously evaluated the balance-training program studied in this thesis (3) and found positive effects on fall-related concerns, gait speed, and physical function in older adults up to one year after end of intervention (4, 110). Participants felt more confident and secure in their ability to perform activities of daily life after taken part in the balance-training and found the program to be motivating, valuable, fun, and enjoyable (3, 111). The balance-training program is further described in the Methods section, page 34.

1.9 SELF-EFFICACY

Self-efficacy is the individual's belief in her or his capability to successfully execute a specific type of activity or behavior, and it is largely influenced by past performance and

accomplishments, or mastery experiences (112). The theory of self-efficacy suggests that the stronger the individual's self-efficacy and outcome expectations are, the more likely it is that she or he will initiate and persist with a given activity (112). There is a strong and consistent association between self-efficacy and physical activity among older adults (33, 37, 113). Self-efficacy is found to be especially important for exercise adoption but play a lesser role during maintenance (113).

Fall-related concerns and knowledge of being at risk for falls, fracture, and/or osteoporosis have all been found to influence self-efficacy and outcome expectations for exercise in older adults, and may subsequently limit habitual physical activity (114, 115). On the contrary, positive experiences in managing physical activity and taking chances without being injured can result in increased self-efficacy and resumed activity in older women (115).

1.10 RATIONALE FOR THIS THESIS

Physical activity is one of the most important modifiable factors for healthy aging. It is well established that a physically active life helps to retain bone and muscle mass, as well as balance performance, essential for the increasing number of older adults with osteoporosis (6, 20, 24). However, physical activity is a complex behavior and there still limited knowledge of the correlates for habitual physical activity, including sedentary behavior, in older individuals with osteoporosis. Fall-related concerns and impaired balance can result in low habitual physical activity (88), a major risk factor for lifestyle related diseases (20, 22, 30). A deeper understanding of perceptions and experiences of physical activity, as well as factors influencing habitual physical activity may provide important knowledge to be used clinically and when designing interventions. Both quantitative and qualitative studies are needed to explore these associations.

Although systematic reviews have shown that physical activity interventions can increase daily step count (27, 28) and that exercise programs can reduce fall-related concerns in community-dwelling older adults (86), the effects on habitual physical activity and HRQoL following a balance-training intervention remain unclear. Our group has developed a 12-week balance-training program for older adults,(3) and the evaluation of the program found that older adults with osteoporosis participating in the balance-training improved their fall-related self-efficacy, gait speed, balance performance, and physical function compared to controls (4). We hypothesized that this balance-training also would contribute to higher habitual physical activity levels and improved HRQoL. The possible pathways for this is described in Figure 5.

Further, it is essential to use valid and reliable methods when assessing physical activity and movement sensors can provide information on steps per day, an objective method for describing habitual physical activity level. However, altered movement pattern in older adults could influence the accuracy of the measurement. Comparison of steps per day derived from pedometers and accelerometers can determine how well these two types of instruments assess step counts in an older population with chronic disease and fall-related concerns.

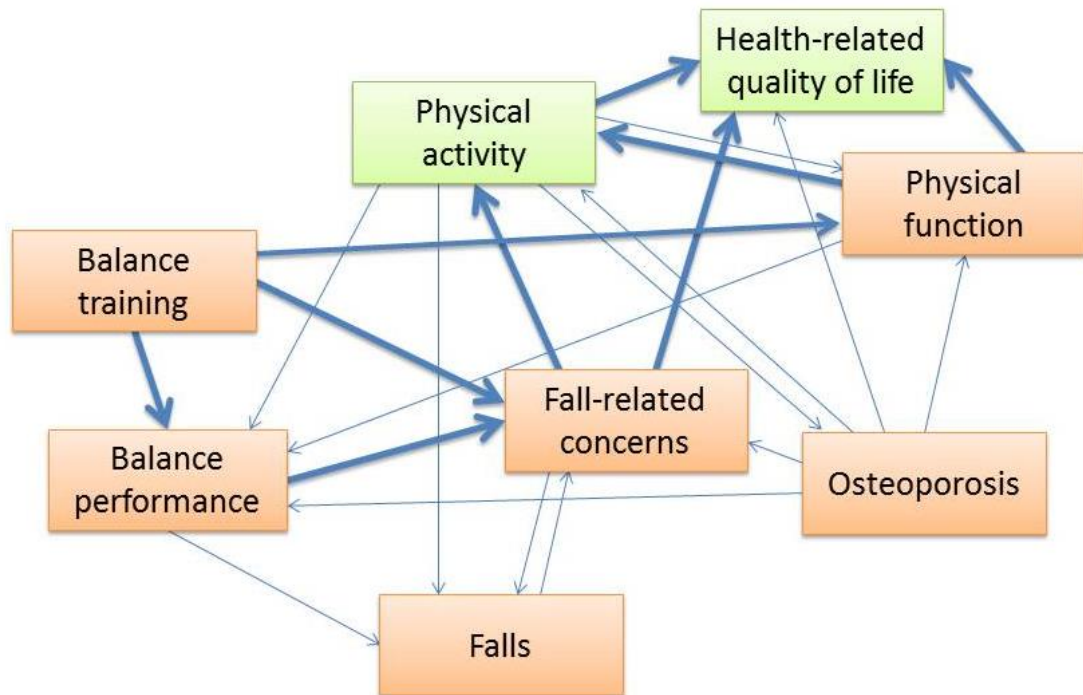


Figure 5. Associations between concepts in this thesis found in previous research. Other relationships might also exist that are not characterized in the figure. Bold arrows indicate the hypothesized pathways for possible effects of the balance-training program on habitual physical activity and health-related quality of life.

2 AIMS

The overall aim of this thesis was to explore correlates for physical activity in community-dwelling older adults with osteoporosis and increased risk of falling, and to evaluate whether a specific and progressive balance-training program focusing on dual- and multi-task exercises for older adults had any short- and long-term effects on objectively measured habitual physical activity and HRQoL.

Specific aims were:

Study I: To describe objectively measured physical activity levels and patterns among older adults with osteoporosis, impaired balance, and fear of falling, and to explore the associations with gait, balance performance, falls self-efficacy, and HRQoL.

Study II: To compare self-reported pedometer steps with accelerometer steps in older adults with osteoporosis, under free-living conditions.

Study III: To evaluate short- and long-term effects of a balance-training program on objectively measured habitual physical activity in older adults with osteoporosis as a primary aim. Furthermore, to evaluate short-term effects of the balance-training on HRQoL, and to study whether any effects on physical activity were associated with changes in HRQoL, gait speed, balance performance, fall-related self-efficacy, and physical function as secondary aims.

Study IV: To describe perceptions and experiences of physical activity and factors that influence habitual physical activity among older adults with osteoporosis, impaired balance, and fear of falling.

3 METHODS

3.1 STUDY DESIGN

Four studies are included in this thesis, all with disparate design: **Study I** is a cross-sectional study; **Study II** is a methodological study on physical activity assessment; **Study III** is a randomized controlled study with short and long-term follow-up evaluating a balance-training intervention (BETA-OP study, Clinical Trials NCT01417598); **Study IV** is a qualitative study applying interpretive content analysis with an inductive approach.

3.2 ETHICAL APPROVAL

All studies follow the Helsinki Declaration, and ethical approval was obtained from the Regional board of ethics in Stockholm (Dnr: 2006/151-31, 2009/819-32, 2010/1472-32, and 2012/1829-32).

3.3 PARTICIPANTS

Participants in all four studies originate from the BETA-OP study, with additional participants in Study II from the Parkinson's disease part of the BETA study (BETA-PD). An overview of sample sizes and dropouts is presented in Figure 6 and characteristics of the BETA-OP participants in the different studies are presented in Table 1. The age span in all four studies was 66-86 years.

Participants were recruited to the BETA-OP study by advertisements in local newspapers in Stockholm County, through the Swedish Osteoporosis Society, and from the endocrinology clinic at the Karolinska University Hospital. Eligible participants were community-dwelling women and men, 65 years or older, living in Stockholm County, with osteoporosis objectively diagnosed via DXA-scan in the hip and lumbar back, and with impaired balance and fall-related concerns, determined by interviews and tests at baseline assessments.

Exclusion criteria were fall-related fractures during the last year, Mini-Mental State Examination (MMSE) score <24 (116), other diseases (for example severe cardio-vascular, pulmonary or neurological disease) with symptoms that might influence participating in the training program, or inability to walk indoors without aid.

Sample size was calculated on the primary outcome variable in the BETA-OP study, Falls Efficacy Scale-International (FES-I), resulting in 21 participants in each of three groups to provide 80% power at the 0.05 significance level (two-sided). Additional sample size analysis was conducted for Study III using steps per day as primary outcome, based on previous studies on older populations, which resulted in similar estimated group sizes (n=19). To allow for post-randomization dropouts the aim was to recruit a total of 100 participants. Out of 351 persons that reported interest to take part in the study, 96 (94 women/2 men) met the inclusion criteria and were included.

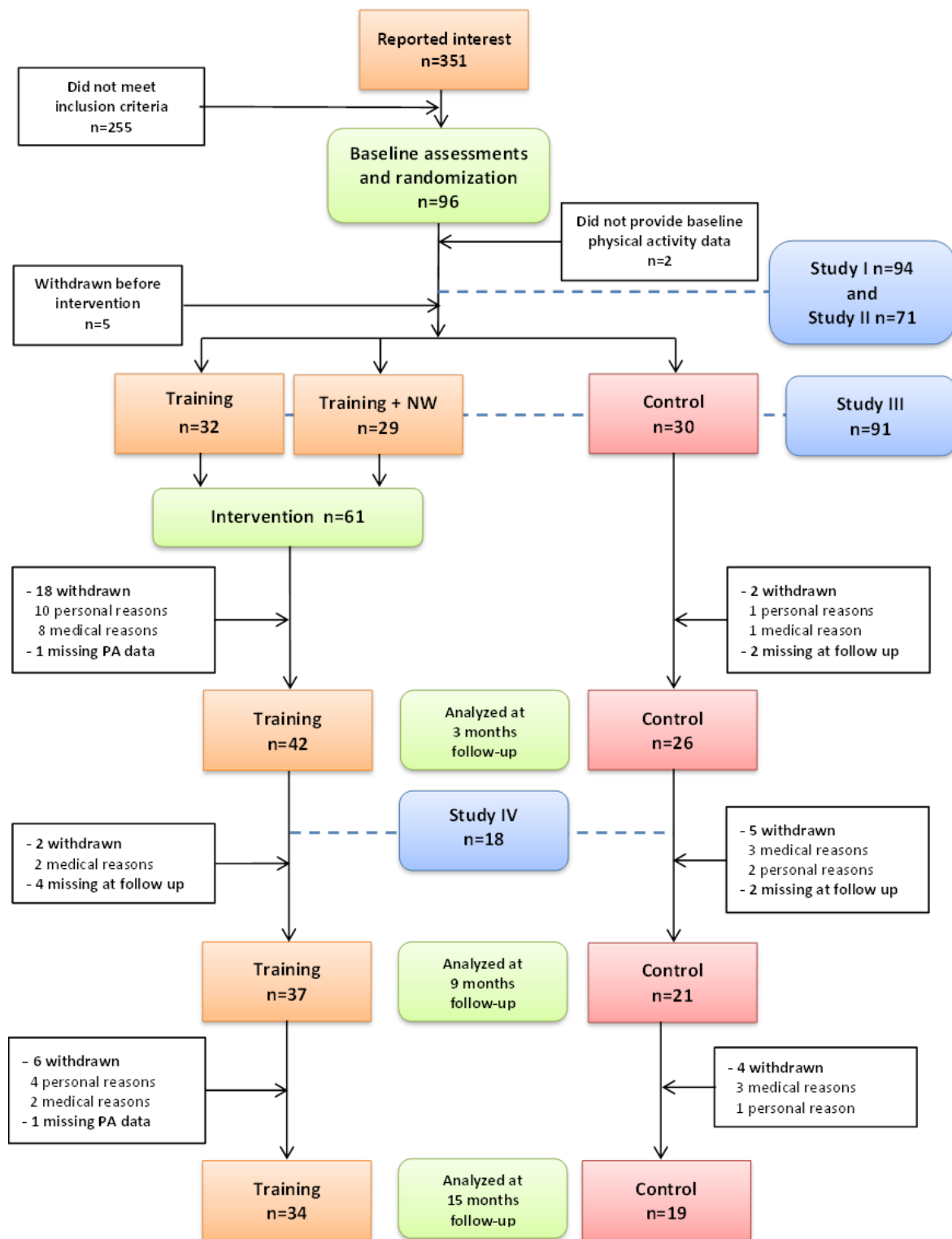


Figure 6. Flowchart describing the inclusion and randomization process, sample sizes and point in time for the four different studies, numbers of participants lost to 3, 9, and 15 month follow-up and reasons for withdrawal.

Randomization was performed in blocks of nine into two intervention groups, Training, and Training+Nordic Walking (NW) and one control group. Participants picked a sealed envelope after finishing the baseline testing for allocation to groups.

The participants from the BETA-PD study included in Study II were recruited through advertisements in local newspapers in Stockholm County, through the Swedish Parkinson Association, and from Karolinska University Hospital. Participants had to be community-dwelling women and men, 60 years or older, living in Stockholm County, with a clinical diagnosis of idiopathic Parkinson's disease according to the definition of the Queen Square Brain Bank (117), Hoehn & Yahr scores of 2–3 (118), and at least three weeks of stable anti-Parkinson's medication. Exclusion criteria were atypical Parkinson's disease, MMSE score <24 (116), other existing neuromuscular disorders or medical conditions that substantially influence gait and balance performance, or inability to walk indoors without aid. (The BETA-PD study is not within the scope of this thesis and these participants will not be further described.)

3.3.1 Study I and II

Out of 96 randomized participants, two participants withdrew before providing physical activity data at baseline assessments, thus 94 individuals were included in Study I. Study II included 71 participants who simultaneously wore a pedometer and an accelerometer at baseline assessment, and an additional 73 participants from the BETA-PD study.

3.3.2 Study III

A total of five participants withdrew after randomization but before the intervention started, and remaining 91 participants were included in Study III. Only those participants who met our a priori set goal of attendance, 24 out of 36 sessions, were included in follow-up. Sixty-eight participants completed the 3 month follow-up, 58 participants completed the 9 month follow-up, and 53 participants completed the 15 month follow-up.

3.3.3 Study IV

In Study IV, 18 informants with a wide range of habitual physical activity levels, 1,927–11,024 steps per day, were purposely recruited both from the intervention groups (Training n=12, and Training+NW n=3) and from the control group (n=3). Informants who had taken part in the balance-training were interviewed five months after the end of the intervention.

3.4 DATA COLLECTION

3.4.1 Physical activity

Physical activity was objectively assessed with two types of movement sensors: pedometer (Yamax LS2000, Yamax Corporation, Japan) and accelerometer (Actigraph GT1M or GT3X+, ActiGraph, USA). Participants were asked to wear the sensors for seven consecutive days

Table 1. Background characteristics of the BETA-OP participants in Studies I, II, III and IV.

Variables	Study I	Study II	Study III		Study IV
	n=94	BETA(OP) n=71	Intervention n=61	Control n=30	n=18
Women/men	92 (98)/2 (2)	69 (97)/2 (3)	60 (98)/1 (2)	29 (97)/1 (3)	18 (100)/0 (0)
Age (years) ¹	75.6 (5.4)	75.3 (5.5)	75.7 (5.8)	75.2 (4.6)	75.5 (6.0)
BMI (kg/m ²) ¹	24.8 (4.1)	25.0 (4.2)	24.5 (4.0)	25.4 (4.2)	24.3 (4.1)
University education	42 (45)	31 (44)	28 (46)	14 (47)	5 (28)
Living alone	56 (60)	44 (62)	36 (59)	19 (63)	12 (67)
Living in apartment	74 (79)	57 (80)	47 (77)	25 (83)	16 (89)
Never or ex-smoker	91 (97)	68 (96)	59 (97)	29 (97)	17 (94)
Spine fracture*	20 (21)	15 (21)	13 (21)	5 (17)	1 (6)
Lower extremity fracture*	11 (12)	8 (11)	10 (16)	1 (3)	3 (17)
Upper extremity fracture*	33 (35)	26 (37)	24 (39)	9 (30)	6 (33)
Experienced a fall, last year	41 (44)	30 (42)	26 (43)	15 (50)	4 (22)
Use walking-aid outdoor	38 (40)	26 (37)	22 (36)	15 (50)	5 (28)
CVD	49 (52)	35 (49)	33 (54)	14 (47)	10 (56)
Diabetes	3 (3)	3 (4)	3 (5)	0	0
COPD or asthma	13 (14)	7 (11)	8 (13)	5 (17)	0
Stroke	6 (6)	8 (11)	5 (8)	1 (3)	2 (11)
FES-I ²	27 (24-33)	27 (24-34)	26 (24-34)	27.5 (23-30)	29 (24-35)
Steps (steps/day) ¹	6,201 (3,107)	6,047 (2,892)	6,209 (2,842)	6,313 (3,734)	6,218 (3,098)
<5,000 steps/day	37 (39)	27 (38)	23 (38)	13 (43)	6 (33)
SF-36, Physical Component Summary ²	40.3 (34.5-45.3)	41.6 (33.0-47.4)	39.7 (33.7-45.3)	41.4 (33.0-47.2)	43.2 (28.2-50.4)
SF-36, Mental Component Summary ²	50.6 (38.5-57.9)	51.2 (42.9-59.1)	49.1 (36.2-56.4)	53.6 (47.2-60.1)	51.5 (39.4-59.5)

Values presented are number (%) or ¹mean (SD), and ²median (IQR). BMI=body mass index, CVD=cardiovascular disease (hypertension, coronary artery disease, myocardial infarction, heart failure), COPD= chronic obstructive pulmonary disease, FES-I=Falls Efficacy Scale International, SF-36=Short Form 36-item Health Survey. *Fractures experienced last 10 years.

during all waking hours (excluding showering and swimming) and to write down the number of steps registered by the pedometer at the end of each day, as well as the time when they put on and removed the sensors on a log sheet. Instructions were given on how to open and reset the pedometer, and how to wear the accelerometer and the pedometer. The pedometer was attached either at the waistband of clothing to the same belt as the accelerometer, in the midline of the thigh, and the accelerometer was worn at the side of the waist attached to an elastic belt (Figure 7). At baseline assessment, 71 participants were equipped with both a pedometer and an accelerometer, whereas 23 participants wore only a pedometer (due to limited access to accelerometers). Background characteristics did not differ between those who wore two sensors and those who only wore the pedometer. At all follow-up assessments, all participants wore both sensors. Accelerometer data were downloaded and processed in ActiLife 6 software using the default filter setting. More than 90 consecutive minutes of zero counts was considered non-wear time and ≥ 600 minutes daily wear time was considered a valid day (119).



Figure 7. Placement of pedometer (left) and accelerometer (right).

The primary outcome in Study I and III was mean number of steps per day, and participants with at least three valid days of pedometer or accelerometer derived steps were included (120). When valid accelerometer data were provided, accelerometer-derived steps per day were used, otherwise, pedometer-derived steps per day were used for analysis. Mean number of steps per day were also dichotomized into two categories: $< 5,000$ steps per day or $\geq 5,000$ steps per day for analyses (25, 30). The primary outcome variable in Study II was mean number of steps per day and participants with at least three days of simultaneous data from both movement sensors were included.

Additional outcome variables for physical activity in Study I were steps per day dichotomized into $< 7,100$ steps per day or $\geq 7,100$ (25) and accelerometer counts from the vertical axis analyzed as daily time in different physical activity intensities and time in MVPA per week, both total time and in ≥ 10 minute bouts. Accelerometer cut-points used were: sedentary behavior, 0-99 counts per minute (cpm); low intensity, 100-759 cpm; moderate intensity from lifestyle activities (such as sweeping, mopping, and vacuuming activities), 760-2,019 cpm; and moderate or higher ambulatory activities (MVPA), $\geq 2,020$ cpm (57).

Additional outcome variables for physical activity in Study III were accelerometer counts from the vertical axis analyzed as number of sedentary bouts per day, mean and maximum length of sedentary bouts in minutes per day, total time in MVPA per day, or ≥ 150 minutes per week in ≥ 10 minute bouts of MVPA. Accelerometer cut-off points used were: 0-99 cpm for sedentary time and $\geq 1,041$ cpm for MVPA (56).

Self-reported physical activity was also assessed with a single question: ‘What exercise habits do you have right now?’ and with the Frändin-Grimby activity scale (121). Self-reported physical activity is not used as an outcome variable in the studies in this thesis.

3.4.2 Health-related quality of life

Health-related quality of life was assessed using the SF-36 questionnaire, a generic measure of HRQoL (66). It consists of 36 questions which yield to eight subscales: physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE) and mental health (MH). The subscales can be summarized in two sub-domains: Physical Component Sum (PCS) regarding physical health, and Mental Component Sum (MCS) for mental health (122). Outcome variables used in Study I were values from the eight subscales and the two sum scores, and in Study III values from the two sum scores. All eight subscales range 0-100, with higher scores indicating better HRQoL.

3.4.3 Balance performance

Balance performance was assessed with the Modified Figure Eight test (MFE) and one-leg stance (123, 124). The MFE is performed on a figure eight marked on the floor with a 4 cm wide taped line, each circle 163 cm inner diameter. Participants walked two complete figures of eight on the marked line as fast as possible, and time and number of oversteps (i.e. no part of the shoe touches the line) were noted. For one-leg stance, each participant was asked to stand first on their right and then on their left leg with hip and knee slightly flexed, for as long as possible (maximum 30 seconds), with eyes open and arms hanging down. Both tests were performed three times. Mean time in seconds and number of oversteps for MFE, and mean time in seconds for each leg in one-leg stance were used as outcome variables in Study I and III.

3.4.4 Gait speed

Gait speed was assessed using a walkway system with embedded pressure sensors that provide information about spatial and temporal gait parameters (GAITRite walkway, CIR systems Inc., USA) (125). Participants were asked to walk back and forth three times, first at a self-selected comfortable (normal) speed and then as fast as possible, without tripping or falling. Mean gait speed (m/s) at normal speed and fast speed were used as outcome variables in Study I and III.

3.4.5 Fall-related concerns

A single-item question: ‘In general, are you afraid of falling?’, with possible responses being ‘not at all’, ‘a little’, ‘quite a bit’ and ‘very much’ was used to assess fear of falling as an inclusion criterion (126). The FES-I questionnaire (127) was used to assess fall-related concerns in Study I and III. Outcome variable was the sum score from the FES-I ranging from 16-64. A lower score indicates lower concern about falling.

3.4.6 Physical function

Physical function was assessed by self-report using the function component of the questionnaire Late-Life Function and Disability Instrument (LLFDI) (128). The function component consists of three subscales: upper extremity function, basic lower extremity function, and advanced lower extremity function, and an additional overall score. The advanced lower extremity subscale consists of 11 questions, about ability to go hiking, brisk walking or climbing stairs without rails for example, and was used as an outcome variable in Study III. The scores range from 0 to 100, with higher scores indicating better ability.

3.4.7 Qualitative data

In Study IV, individual semi-structured interviews (51, 129) were conducted by the author to gather information and provide insight about perceptions and experiences of physical activity and factors that influence habitual physical activity. An interview guide with open-ended questions was used and physical activity was defined both as everyday activities, including transportation, and as activities performed for the purpose of being physically active, such as walking for exercise, going to a gym, or exercising at home.

3.5 PROCEDURES

3.5.1 Study I, II and III

Assessments took place at a movement laboratory at either Karolinska Institutet or Karolinska University Hospital with experienced physical therapists as test leaders, following a pre-designed protocol. At baseline, participants were first informed about the study protocol and individual informed written consent was obtained. Height and weight were measured using a stadiometer and a scale; thereafter an initial trial session of gait- and balance tests was performed. After the trial session, the participants randomly either started with answering questionnaires, followed by physical test assessments, or vice versa. Finally, instructions were given on how to wear the movement sensors. Participants wore light clothing and comfortable indoor shoes during the tests. Follow-up assessments at 3, 9 and 15 months included the same procedure, except for the height and weight measurement and the trial session. Data were collected between November 2009 and December 2012. Randomization was performed after the baseline test session. Researchers were blinded to group allocation at baseline assessments, but not at follow-up assessments.

3.5.2 Study IV

Interviews were conducted between February and October 2011 at a movement laboratory at Karolinska Institutet or at Karolinska University Hospital, both locations familiar to the informants. Information was given that the interview would be open and focused on the informant's own perception and experience of physical activity, and that all identifying information would be removed from interview transcripts. The interviews were recorded on a digital voice recorder and lasted between 32 minutes and 1 hour 15 minutes.

3.6 INTERVENTION

The balance-training intervention in Study III has been described in a previous publication providing both a detailed description of the program and how the different components in the program relate to exercise physiology and balance control theories (3). In short, the exercises in the balance-training program were progressive and specific to functional balance and incorporated dual- and multi-task exercises, for example counting, carrying a tray, or having to avoid obstacles. Even though the training was performed as group sessions, the exercises were individually adjusted for each participant, with the aim to challenge their balance control. All exercises could be performed in three degrees of difficulty: basic, moderate, and advanced. Every session included exercises while sitting on a large balance ball, while standing, and while walking. The exercises differed across sessions to achieve variety, but every exercise was repeated later on in the program, often in a more challenging form. Figure 8 illustrates the various components in the program and how they are associated with different balance control systems.

The intervention lasted for 12 weeks, with three 45 minute balance-training sessions per week. The groups consisted of 6-10 participants with two or three physical therapists present at each session to ensure participant safety and allow individual progression of exercises. Participants randomized to the Training+NW were also provided with walking poles and an activity diary. They were instructed to perform NW for 30 minutes at least three times per week, on their own, in addition to the balance-training. No instructions about continued balance-training or physical activity were given at the end of the intervention. The participants randomized to control group were offered to participate in balance-training when the study period was completed.

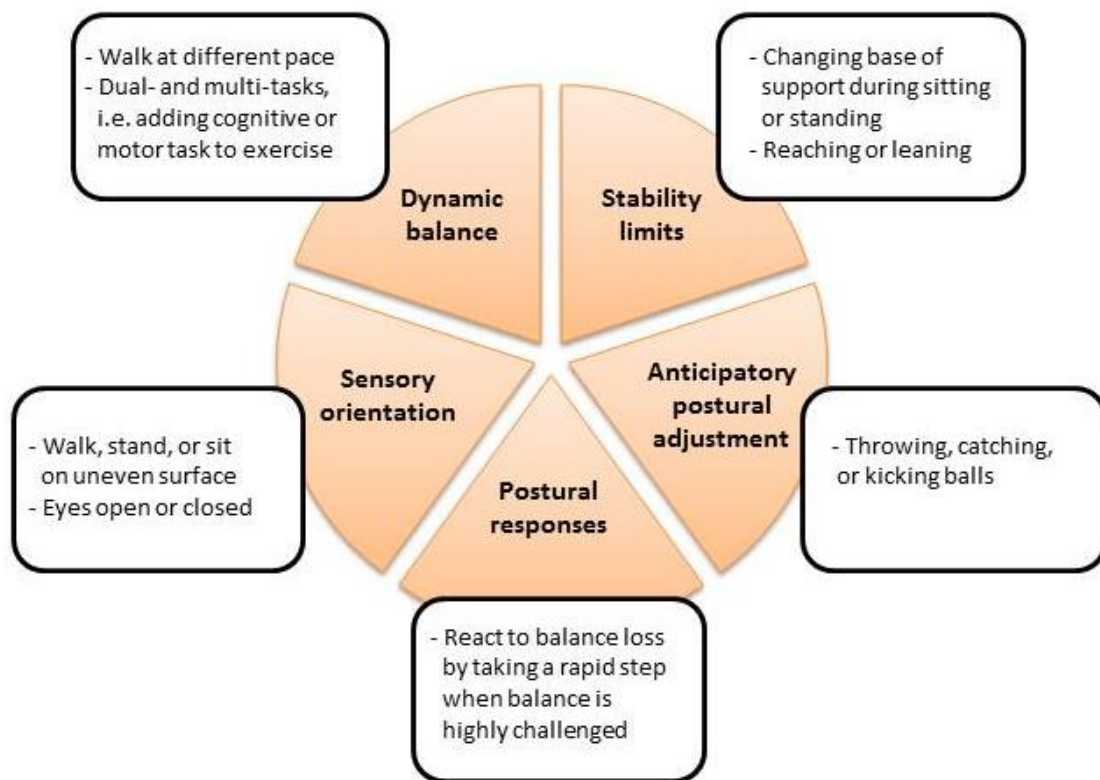


Figure 8. Illustration of the balance-training program and the various components associated with the different systems that contribute to balance control.

3.7 DATA ANALYSES

3.7.1 Changes from planned analysis in protocol

The original study protocol included two intervention groups: Training and Training+NW. Analyses of self-reported physical activity and activity diaries from the Training+NW group showed that many of the participants in the Training group had walking or NW as a regular activity, in addition to the balance-training, and that all participants in the Training+NW group did not adhere to the study protocol regarding NW(4). This implied that there was no difference between the two groups regarding regular walking or NW, as addition activity to the balance-training. Due to the similar walking behavior in the two intervention groups and to maintain statistical power, the analyses in Study III computed on two groups: one intervention group, merged by Training and Training+NW, and one control group.

3.7.2 Statistical methods

Table 2 lists the statistical methods used in the thesis. Statistical analyses in Study I and III were computed in Stata, version 11.2 (StataCorp LP, USA). Statistical analyses in Study II were performed in SPSS version 20.0 (IBM Corp, USA). Data are presented as mean and SD for continuous variables and median and interquartile range (IQR) for ordinal variables. Odds ratios (OR) were determined with 95% confidence intervals (CI), and p-values ≤ 0.05 were considered statistically significant. The final logistical regression model included steps per

day level as outcome variable and treatment group as independent variable, adjusting for mean steps per day at baseline, age, BMI, and use of walking-aid outdoors. The intention to treat analysis in Study III was computed using Multiple Imputation procedures in Stata (130). Estimates from 20 generated datasets were pooled and a logistic regression including all 91 participants was computed using the same multivariate model as in the per-protocol analysis.

Table 2. Statistical methods used in Studies I, II and III.

Methods	Study I	Study II	Study III
Descriptive statistics			
Number (n), percent (%)	X		X
Median, interquartile range (IQR)	X		X
Mean, standard deviation (SD)	X	X	X
Statistical methods			
Two sample t-test	X		X
Paired sample t-test		X	X
Wilcoxon rank-sum test (Mann-Whitney)	X		X
Wilcoxon signed-rank test		X	X
Chi-squared test	X		X
Multivariate logistic regression	X		X
Logistic Generalized Estimating Equation (GEE)			X
Bland-Altman method		X	
Multiple Imputation			X
Intraclass correlation coefficients (ICC)		X	

3.7.3 Qualitative method

In Study IV, interpretive content analysis with an inductive approach was used to analyze the transcripts, consisting of 630 meaning units. The analysis was inspired by Baxter's (131) description of thematic content analysis, a holistic analysis with a red thread linking the themes. The process followed the criteria for credibility, dependability, and transferability as described by Elo and colleagues (129) to ensure the quality of the findings and trustworthiness of the interpretations. The analysis was carried out in several steps: interviews were read several times to obtain a general impression of the content; all parts of the interviews related to the research aim were extracted to meaning units that were condensed and labeled with a code; finally, the codes were compared and organized into similar areas, and interpreted in relation to the aim. The whole process involved going back and forth between the different steps to capture the key aspects of the themes in the raw data, and the findings were repeatedly discussed by all authors until consensus was reached. Table 3 presents examples of the interpretive content analysis process from meaning units to subthemes.

Table 3. Examples of the interpretive content analysis process from meaning units (raw data) to subthemes.

Meaning-unit	Condensed meaning unit	Codes	Subthemes
It's this thing about moving, you can't do it like before. But there is nothing to do about it...so...I'm not gonna cry over it. I have to accept it.	You can't move like before, but you have to accept that	Age and osteoporosis limitations	Accept body limitations
It's this thing with me, thinking that I'll be walking like my old aunt, who almost looked down at the ground, and my mother who had such terrible back pain ...and.... She had a lot of fractures and.... It's more what's in...if that's how my future will be.	I think about my aunt and my mother with all their back problems, if that is how my future will be	Concern about future	Living with concerns and uncertainties
I have a stool I use when I have to get up a bit, reach high up. But I hold on really tight.... It's not like [<i>swishing sound</i>]...just up! Oh no, I'm really careful how I, take one step at a time and... hold on tight.	I hold on tight when I have to climb onto a stool, I am very careful	Strategy—be careful	Finding strategies and solutions
Yes, it's very good. Because I believe, actually, that if I didn't have my strength training...I wouldn't be here. I'd been in a wheelchair. Yes, it's very important.	I would be sitting in a wheelchair if it were not for the strength training	A tool to control osteoporosis	Belief in the health effects of physical activity

4 RESULTS

4.1 STUDY I

4.1.1 Physical activity levels and patterns

Mean (SD) steps per day was 6,201 (3,107) for the total population (n=94), ranging from 991 to 17,156 steps per day. Thirty-seven (39 %) participants reported <5,000 steps per day and were classified as Low Active; the 57 participants reporting $\geq 5,000$ steps per day were classified as Active. There were no between-group differences in background characteristics, except for mean age (Low Active: 78 years, Active: 74 years) and proportion of participants who had experienced an upper extremity fracture the last 10 years (Low Active: 19%, Active: 46%). The difference in mean steps per day between Low Active and Active was 4,680 steps per day. Twenty-nine (31%) participants reported $\geq 7,100$ steps per day.

4.1.1.1 Subgroup analyses of physical activity

Accelerometer data was obtained from 65 participants, 69 percent of the total sample. There were no significant differences between participants with data from one or both movement sensors. Analyses of time in different physical activity intensities showed that three participants (5%) met the recommendations of 150 minutes or more of MVPA per week, accumulated in bouts of at least 10 minutes. When all minutes spent in MVPA were used for calculation, regardless of bout length, 29 (45%) participants met the recommendation, all in the Active group. Nineteen participants with accelerometer data reported $\geq 7,100$ steps per day and all of them met the recommendation (all MVPA minutes used). On average 11 hours per day (or 77% of wear time) were spent sedentary, almost two hours (14%) in low intensity activity, 49 minutes (6%) in moderate lifestyle activity and 28 minutes (3%) in moderate or higher ambulatory activity.

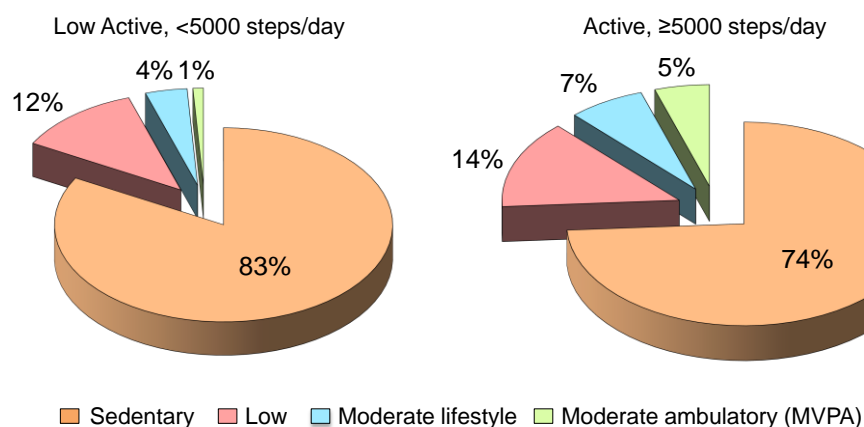


Figure 9. Physical activity pattern presented as percentage of wear time (minimum 10 hours per day) spent in different physical activity intensities for Low Active (<5,000 steps/day), n=26, and Active ($\geq 5,000$ steps/day), n=39, participants. There were significant differences between Low Active and Active in all intensities, $p < 0.05$.

Analyses of Low Active (n=26) and Active participants (n=39) with accelerometer data showed statistically significant between-group differences regarding time spent in different physical activity intensities. Low Active participants spent on average eight minutes per day in MVPA and 11h 26 min per day being sedentary. Percentages of wear time spent in different intensities for Low Active and Active participants are shown in Figure 9.

4.1.2 Associations with gait, balance performance, fall-related concerns, and HRQoL

Low Active participants had slower gait speed, poorer balance performance, and lower HRQoL compared to Active participants. No associations between physical activity and fall-related concerns were found. Table 4 shows outcome variables with statistically significant differences between Low Active and Active and results from age-adjusted logistic regression analyses.

4.1.3 Supplementary results - HRQoL

There was a moderate positive linear relationship between steps per day and PF and PCS (Spearman's rho: 0.45 and 0.44, $p < 0.001$, respectively) for the total sample (n=94) in Study I. Supplementary descriptive results regarding the participants HRQoL and comparisons with normative values are shown in Figure 10. Participants aged 75 and over had significant higher scores in PF, RP and VT. Younger participants had significant lower scores than normative values in RP and BP.

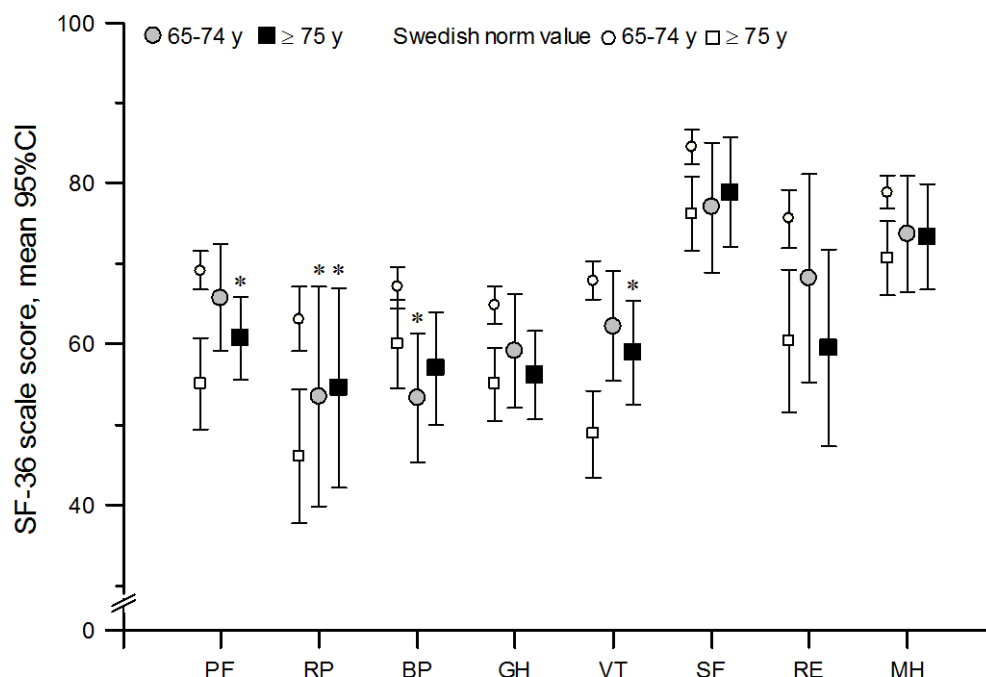


Figure 10. Scores from Short-Form 36-item Health Survey (SF-36) at baseline for female participants aged 65-74 years and 75 years or over and comparisons with Swedish normative values. PF=physical functioning, RE=role physical, BP=bodily pain, GH=general health, VT=vitality, SF=social functioning, RE= role emotional, MH=mental health.

Table 4. Values for variables with significant differences between participants categorized as Low Active with <5,000 steps/day (n= 37) and Active with ≥5,000 steps/day (n=57) and results of the logistic regression analysis.

Variables	Low Active	Active	p-value	OR, age-adjusted	p-value
Steps/day ¹	3,363 (981)	8,043 (2,577)	<0.001		
<i>Gait¹</i>					
Gait speed, normal, m/s	1.07 (0.19)	1.23 (0.22)	<0.001	1.03 (1.01-1.06)	0.010
Step length, normal, cm	57.1 (7.7)	64.9 (8.1)	<0.001	1.13 (1.05-1.21)	0.001
Gait speed, fast, m/s	1.36 (0.26)	1.59 (0.25)	<0.001	1.03 (1.01-1.05)	0.002
Step length, fast, cm	62.8 (9.0)	72.1 (8.8)	<0.001	1.11 (1.05-1.18)	<0.001
<i>Balance performance²</i>					
MFE, time, s	29.0 (24.3-38.9)	24.2 (21.2-28.7)	0.009	0.96 (0.92-1.00)	0.063
MFE, oversteps, n	5.0 (2.0-12.0)	2.3 (0.7-4.3)	<0.001	0.88 (0.79-0.98)	0.016
One-leg stance, right, s	3.9 (2.2-11.6)	8.8 (3.0-21.2)	0.015	1.04 (0.98-1.09)	0.159
One-leg stance, left, s	4.8 (2.2-18.6)	8.9 (2.5-19.6)	0.013	1.04 (0.98-1.10)	0.176
<i>Health-related quality of life, SF-36²</i>					
Physical function	55 (45-70)	70 (60-80)	0.002	1.04 (1.01-1.06)	0.004
Role physical	25 (0-100)	75 (25-100)	0.008	1.02 (1.00-1.03)	0.006
General health	50 (40-62)	62 (49-80)	0.038	1.02 (0.99-1.04)	0.154
Physical component sum	35.2 (28.3-40.3)	43.8 (37.8-48.1)	<0.001	1.10 (1.04-1.17)	0.001

Values presented are ¹mean (SD) or ²median (IQR). Statistics: ¹Two sample t-test or ²Wilcoxon rank-sum test. Odds ratios (OR) are presented with 95% confidence intervals (CI). MFE=Modified figure of eight test.

4.2 STUDY II

Sixty-one participants (86%) with osteoporosis and 51 participants (70%) with Parkinson's disease provided simultaneously recorded data from the movement sensors for three days or more. Reasons for lost data in the BETA-OP group were equipment malfunction, losing the device or not returning the diary. Reasons for lost data in the BETA-PD group were difficulties opening and resetting the pedometer, not recording number of steps, forgetting to reset the pedometer, or accidentally wearing the pedometer upside-down. There was a high agreement between self-reported pedometer steps and accelerometer derived steps in the BETA-OP group: $6,035 \pm 3,257$ (pedometer) and $6,047 \pm 2,957$ (accelerometer), $p=0.956$. In the BETA-PD group were number of self-reported pedometer steps significantly lower than accelerometer derived steps: $4,164 \pm 3,708$ (pedometer) and $4,967 \pm 3,191$ (accelerometer), $p=0.002$. The ICC in the BETA-OP group was 0.847 with a 95% CI (0.757- 0.905), ($p<0.001$). Bland-Altman plots demonstrated wide limits of agreement between the sensors in both the BETA-OP group (range=6,794 steps) and the BETA-PD group (range=6,911 steps). See Figure 11.

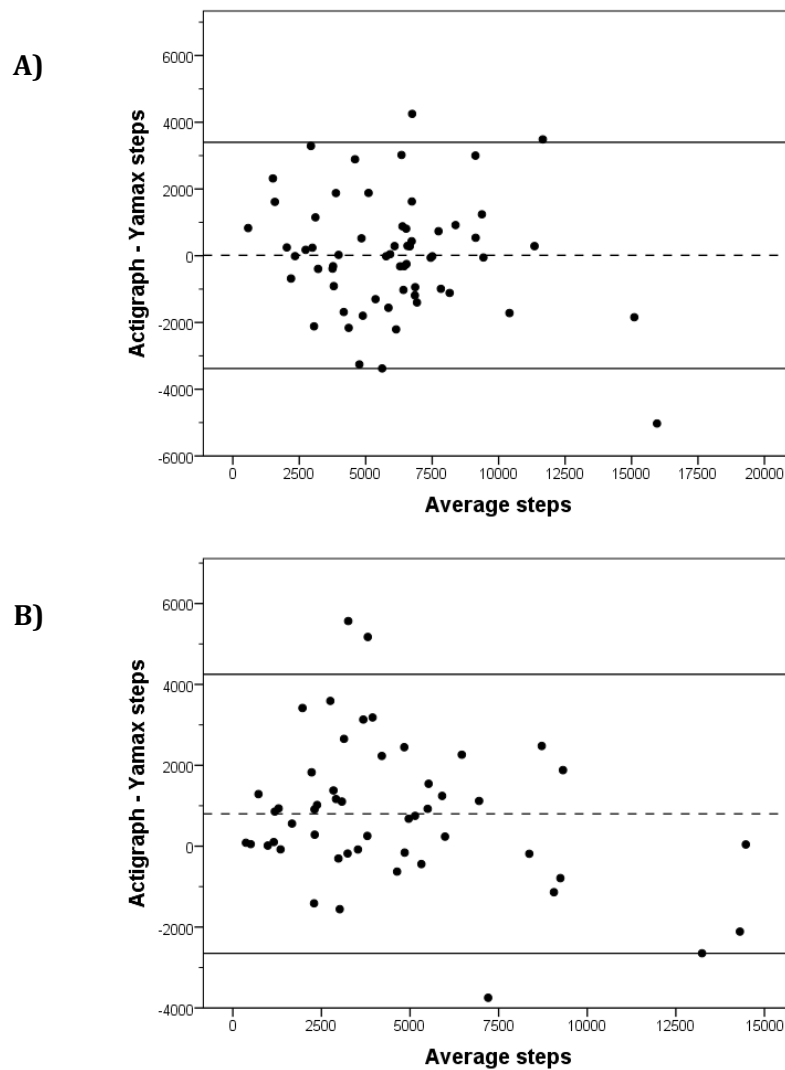


Figure 11. Bland-Altman plots for the osteoporosis group (A) and Parkinson's disease group (B), respectively. The plots illustrate, in average step counts per day, the differences between the Actigraph accelerometer and the Yamax LS2000 pedometer (accelerometer minus pedometer) (on the y-axis) against their average values (on the x-axis). Bold lines indicate 95% upper and lower limits of agreement and bold dotted lines indicate the mean difference between instruments.

4.3 STUDY III

Sixty-eight participants (75%) completed the post-intervention follow-up at 3 months, 58 (64%) completed the 9 month follow-up, and 53 (58%) completed the 15 month follow-up (Figure 6). One participant was lost to follow-up due to insufficient adherence to the training (<24 sessions). There were no significant differences on any baseline characteristics between those who completed and those who were lost to the 3 month follow-up. A higher proportion of the participants in the intervention group, 31% compared to 13% in the control group, were lost to the 3 month follow-up; although this difference was non-significant ($p = 0.066$). All participants in the control group who were lost to the 9 month follow-up had a daily step level of <5,000, which biased the results ($p=0.008$), and data at 9 month follow-up were not further analyzed.

There were no differences in proportion of participants who were lost to the 15 month follow-up between treatment groups ($p=0.49$). Analysis of all 38 participants who were lost at the end of the study showed no differences in physical activity levels or pattern compared to those who completed the whole study period. However, participants lost to follow-up had more health problems (cardio-vascular disease, stroke and vertebral compression fractures) and lower physical function (slower fast gait speed and lower physical function score in SF-36) at baseline.

4.3.1 Effects of the balance-training on physical activity

Short and long-term results for steps per day (per protocol) are shown in Table 5. Per-protocol analysis of the 68 participants that completed the 3 month follow-up showed that the OR for having a daily step-count $\geq 5,000$ was 6.17 (1.23-30.91), $p=0.027$, for the intervention group compared to the control group. A sensitivity analysis was computed using Multiple Imputation to assess if the 23 participants lost to follow-up might have introduced bias, but the results showed little difference: OR 7.14 (1.41-36.19), $p=0.018$. The longitudinal analysis (Generalized Estimated Equation) including all 91 participants showed that the OR for having a daily step-count $\geq 5,000$ at 15 months was 2.02 (95% CI 0.88-4.64), $p=0.096$, for the intervention group compared to the control group. An additional longitudinal analysis excluding the results at 9 month follow-up showed a similar, but significant, result as the analysis including all follow-up data: OR 2.91 (95% CI 1.15 to 7.36) ($p=0.024$).

4.3.1.1 Subgroup analyses of physical activity

At the 3 month follow-up, accelerometer data were obtained from 50 participants: 30 in the intervention group and 20 in the control group. None of the variables examined: number of sedentary bouts, length of sedentary bouts, time in MVPA, or ≥ 150 minutes per week in ≥ 10 minute bouts of MVPA, showed statistically significant between-group differences.

Table 5. Short- and long-term values for habitual physical activity (steps per day).

Outcome measure	Baseline	3 months	9 months	15 months
Intervention group, n	61	42	37	34
Steps per day, mean (SD)	6,209 (2,842)	6,064 (2,430)	5,917 (2,062)	6,013 (2,241)
Steps per day, range	1,284-14,181	1,372-12,102	2,588-12,602	1,501-10,728
$\geq 5,000$ steps per day, n (%)	38 (62)	30 (71)	25 (68)	24 (71)
Control group, n	30	26	21	19
Steps per day, mean (SD)	6,313 (3,734)	4,921 (2,890)	7,084 (3,186)	5,698 (2,835)
Steps per day, range	994-17,156	377-13,470	1,509-13,917	228-10,096
$\geq 5,000$ steps per day, n (%)	17 (57)	11 (42)	14 (67)	11 (58)

4.3.2 Supplementary results – physical activity

Twenty-five participants (39%) accumulated 150 minutes per week in bouts of ≥ 10 minutes at baseline assessments when the cut-point $\geq 1,041$ cpm for MVPA was used. Effects of the balance-training on HRQoL

Per-protocol analysis showed no statistically significant between-group differences in HRQoL at 3 month follow-up. The PCS of SF-36 improved from baseline to 3 months in both groups and the MCS improved significantly in the intervention group.

4.3.3 Associations with changes in covariates

No associations were found between physical activity and changes in covariates (HRQoL, gait speed, balance performance, fall-related concerns, lower extremity physical function) from baseline to 3 month follow-up (per protocol analysis, $n=68$).

4.4 STUDY IV

The analysis resulted in one overall theme, comprising two main themes and eight subthemes (Table 6).

Table 6. Overview of the results in Study IV: Overall theme, main themes, and subthemes.

Overall theme	Main themes	Subthemes
Physical activity—a tool for staying healthy with osteoporosis	Being physically active with osteoporosis means having to face challenges	Perceived barriers
		Accepting body limitations
		Living with uncertainties and concerns
		Finding strategies and solutions
	Being physically active gives possibilities to maintain health	Identity as an active person
		Belief in the health effects of physical activity
		Sense of mastery and self-efficacy
		On your own terms

The overall theme found was: ‘*Physical activity—a tool for staying healthy with osteoporosis*’. The women had a strong belief in physical activity as a possible way to maintain health in their life with osteoporosis, which also implied that they believed that they themselves had an important role in achieving this possibility.

I really believe that, if you've got osteoporosis...I think, and that's what you hear and what I've picked up: You have to keep moving, be active...And then some people can be more active and some less...but strengthen your back, your muscles [...] I believe you have to work with your body.

They emphasized the importance of being seen as individuals with their own needs and choices, and described how they had adapted to disease-specific limitations and developed strategies to overcome perceived challenges and barriers, with the aim of being able to use physical activity as a tool. The two main themes were not separate but rather linked to each other like two sides of the same coin, with factors that could act as both barriers to and facilitators of physical activity.

The first main theme, '*Being physically active with osteoporosis means having to face challenges*' interpreted the limitations, barriers, and concerns the informants perceived and experienced as challenges to being physically active. The major perceived barrier to physical activity was weather conditions; all informants talked about how they had to be extremely careful in the wintertime. Another important challenge was to approach the conflicting advice, or lack of advice, about physical activity and osteoporosis given by health care professionals. Most women described how their physicians emphasized activity restrictions rather than promoting physical activity, which was perceived as confusing and in conflict with information in newspapers, on the internet, or from physical therapists.

My doctor told me: 'It's icy, don't go out walking now.' Ok, so what am I supposed to do? Walk indoors?

This theme also included having to find strategies and solutions to face the challenges. Most women had adapted to disease-specific limitations and developed strategies to overcome challenges and barriers to physical activity and they seemed to be able to incorporate the proactive strategies into their daily life without much difficulty. However, living with a fragile body also evoked feelings of uncertainty or fear regarding physical activity.

I've been thinking, maybe I should try strength training.... But, God no, I think, I'm probably like a biscuit. Yes, a cracker.... No, maybe it doesn't work.

Several informants mentioned that they needed more knowledge about the appropriate type of exercise for people with osteoporosis.

The second main theme '*Being physically active gives possibilities to maintain health*', reflected the informants' strong belief in physical activity as tool to maintain health, based upon a positive attitude towards physical activity, and their own experiences of positive effects of physical activity. Many women had searched for and obtained information about the benefits of physical activity for persons with osteoporosis through the media and internet as well as from patient organizations. Reasons for engaging in physical activity were to stay healthy with osteoporosis, to prevent further physical decline, and to combat the effects of aging.

I've started going to a gym a little to run on a treadmill...because when you pound or put pressure...on your bones it builds new [bone mass] and then I think, even though I'm almost seventy, maybe I can build new bone mass too.

This theme was also formed by their perceptions of themselves as active and healthy persons, in spite of their osteoporosis diagnoses, yet with a need of support from others. Added exercise routines gave them a sense of control over their bone health and positive experiences of physical activity contributed to a sense of mastery. Being able to take long walks or perform difficult activities generated increased self-efficacy. The women who had participated in the balance-training declared how the specific training helped to strengthen their physical activity confidence.

Because if you have different diagnoses, it can make you scared of doing certain things. But if you've done this [balance-training]...then you see that you can do it.... To me that was positive.

Many women perceived that the encouragement and guidance they received from their physical therapists were very important, although they also mentioned that they would like more individualized instructions and support.

4.5 SUMMARY OF FINDINGS

Cross-sectional associations were found between physical activity and HRQoL, gait speed (physical function) and balance performance. The RCT found that participation in the balance-training program could increase habitual physical activity, but no mediating effects were found from variables previously shown to increase after the balance-training. The qualitative study provided information both about correlates to physical activity and perceived effects of the balance-training. (Figure 12)

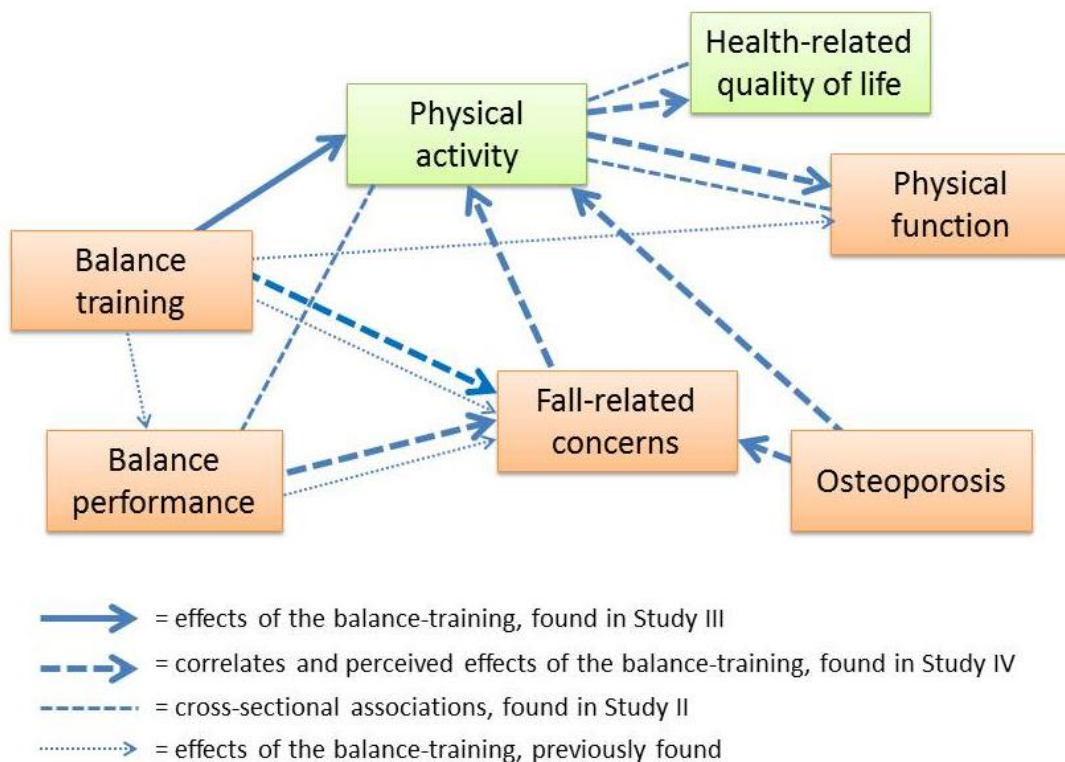


Figure 12. Summary of the findings from Studies I, III and IV regarding correlates for physical activity and the effects of the balance-training on physical activity and HRQoL.

5 DISCUSSION

The studies included in this thesis strived to add to the broader knowledge of effects of physical therapy interventions and of important factors regarding physical activity and HRQoL in older adults. The overall aim was to explore the correlates for physical activity in community-dwelling older adults with osteoporosis and increased risk of falling, and to evaluate whether a specific and progressive balance-training program focusing on dual- and multi-task exercises for older adults has any short- and long-term effects on objectively measured habitual physical activity and HRQoL.

5.1 MAIN FINDINGS

One of the main findings in this thesis was that fall-related concerns do not necessarily imply low levels of habitual physical activity in community-dwelling older adults with osteoporosis. On the contrary, many participants recorded a high number of steps per day. Sixty percent had a physical activity level of $\geq 5,000$ steps per day, and almost one third reached the suggested recommendation for older adults, $\geq 7,100$ steps per day. The women who participated in the interview study perceived physical activity as a tool for staying healthy with osteoporosis and they also believed that they had a responsibility in using this tool. Support and advice from physical therapists regarding suitable physical activity and exercises were perceived as important. However, we also found that 40 percent of the participants did have a low physical activity level, $< 5,000$ steps per day. The low activity level was associated with slower gait speed, poorer balance performance, lower HRQoL, and a more sedentary behavior. We also found that the balance-training intervention had beneficial short-term effects on habitual physical activity, as a significantly higher proportion of the participants in the balance-training reached a level of $\geq 5,000$ steps per day compared to controls, and this is important for overall health (30). This effect was not associated with improvements in HRQoL, gait speed, balance performance or falls self-efficacy, and did not persist through the long-term follow-up, 12 months after cessation of training. Furthermore, steps derived from either a Yamax pedometer or an Actigraph GT1M/GT3X+ accelerometer can be used interchangeably to assess habitual physical activity level in older adults with osteoporosis.

5.2 PHYSICAL ACTIVITY

One of our basic assumptions when planning this research was that older adults with osteoporosis and fall-related concerns would restrict their habitual physical activity as suggested by previous reports (88, 90). This was shown to be inaccurate already at baseline assessment. Even though fall-related concerns and perceived balance problems were inclusion criteria, objective measurement of habitual physical activity demonstrated a wide range of daily steps among the participants, from less than 1,000 steps per day to over 17,000. Six participants (10%) in the intervention group and five (17%) in the control group walked over 10,000 steps per day (data not shown). In Study IV, many women described how they had walking or NW as a regular habit in spite of fall-related concerns, which is consistent with other studies (132-134). This corroborates the findings in both Studies I and III; fall-

related concerns might not be as strongly associated with habitual physical activity in older adults with osteoporosis, as suggested. A possible explanation for this contrasting finding is that associations between physical activity and fall-related concerns previously have been described based on self-report, depending on the individual accurately recalling the duration and intensity of activity. Amount of physical activity may easily be underestimated in older persons as calculations from subjective assessments often are based on activities sustained for longer intervals (34), and the main part of daily physical activity in older adults is performed in low intensity activity spread over the day, which may be harder to recall and estimate. Objective methods, such as accelerometers or pedometers, provide more accurate information based on what activity a person actually does, and not the amount of activity the person perceives or estimates.

To the best of our knowledge, our studies are the first to investigate associations between objectively assessed habitual physical activity and fall-related concerns in older adults with osteoporosis. One recent study has described cross-sectional associations between total daily accelerometer counts fall-related concerns in a general older population, 78 community-dwelling older adults without severe chronic diseases and able to walk indoors without aid (133). Concordant with our findings, no relations were found between habitual physical activity and fall-related concerns (133). Our qualitative data also support these finding. In the interviews, the women described how they had adapted to a life with a fragile body and could continue to be active persons. Most women perceived themselves as being healthy and even though they were afraid of falling, it did not stop them from being active, with the exception of walking outdoors during the winter during snowy and icy weather conditions.

In agreement with our findings, two other studies assessing physical activity by accelerometry in older and middle-aged Swedes (36, 135) found that only a few percent reached the recommended level of 150 minutes of MVPA, if accumulated in bouts of at least 10 minutes. Both these studies, as well as our Study I, used $\geq 2,020$ cpm to define MVPA, which facilitates comparisons. The choice of cut-points and other accelerometer data processing decisions may have a significant influence on outcomes, such as estimates of time in different activity intensities. It is still unclear if there is an optimal cut point when using the Actigraph accelerometer in research on older persons, and recommended MVPA cut-points range from 574 to 3,250 cpm (58). One reason for the wide ranges is that some calibration studies focus mainly on ambulation to determine cut-points, while others include lifestyle activities. It has been suggested that the cut-point for older adults need to be lower than for younger persons due to differences in relative energy expenditure for the same activity (136), which is the reason for our choice to use another, lower, cut-point for MVPA in Study III (56). For comparison, we calculated adherence to physical activity recommendations at baseline using the cut-point in Study III, $\geq 1,041$ cpm. As expected, the results showed a considerably higher proportion of the participants meeting the recommended 150 minutes of MVPA in minimum 10-minute bouts: 39 percent. A study including 2,500 community dwelling older adults, 70-93 years, using the same cut-point, found that 14 percent reached the recommended activity level (137). Nevertheless, it is important to bear in mind when

evaluating adherence to the recommendations by objective assessments that current physical activity recommendations were developed mainly by self-report questionnaire data and interpretations should be done with caution (138).

Swedish and international data from objective assessment of physical activity have shown that adults ≥ 60 years spend an average of 9.4 hours per day, or 65-80 percent of daily time, sedentary (139, 140). Our cross-sectional data suggest that older persons with osteoporosis are even more sedentary. The least active participants, with $< 5,000$ steps per day, spent as much as 11.5 hours sedentary, which corresponds to 83 percent of wear time. Available evidence on objectively assessed sedentary behavior in individuals with chronic conditions or disability is limited and our study is, as far as we know, the first to include individuals with osteoporosis. Percentages of sedentary time in populations with chronic conditions or disability are generally higher than reported for healthy persons. Research on patients with stroke, Parkinson's disease or Multiple Sclerosis – all common patients in physical therapy practice – report 75-88 percent sedentary time (141-143). Sedentary behavior has significant negative effects on metabolism and cardiovascular health, especially when accumulated in long uninterrupted periods (43, 44) and it is therefore important to pay attention to this in physical therapy practice and research. Physical therapy interventions designed to help patients with chronic conditions or disability to reduce sedentary time have a large potential and may produce even greater benefits than for people without disabilities because of the magnitude of sedentary behavior.

The 0-99 cpm cut-point for sedentary time used in Studies I and III is the most commonly used threshold in research including older adults (58). Counts less than 100 per minute typically correspond to sitting and lying (MET < 1.5), but it should be noticed that we did not use the inclinometer function in the GT3X+ accelerometer to actually try to differentiate sitting from standing position and there could potentially be some quiet standing time included in this sedentary data.

Data is scarce on objectively assessed physical activity and gait speed in populations with chronic conditions or disability and we believe that Study I is the first to assess these associations in older adults with osteoporosis. Low Active participants had a slower gait speed compared to Active participants and also compared to normative reference values. Slow gait speed has been shown to correlate with low levels of self-reported physical activity (144, 145) and lower number of steps per day (146) in general older populations. Consistent with our findings, a study including individuals with late effects of polio reporting physical activity levels similar to our sample, found that number of steps was associated with gait speed (147). Due to the cross-sectional design of these studies, it is not possible to conclude whether slow gait speed leads to low activity levels or if the relationship is inversed. Associations between habitual physical activity and gait speed may be explained by lower extremity muscle strength or aerobic capacity (34, 145, 147), but this need to be further investigated.

5.2.1 Effects of the balance-training on physical activity

Our hypothesis, that participation in the balance-training intervention would increase habitual physical activity in community-dwelling older adults with osteoporosis, was confirmed in the short-term evaluation. Participants who had taken part in the intervention had an OR of 6.17 for achieving $\geq 5,000$ steps per day compared to controls. We believe that this is of significant value, since this is an activity level associated with many beneficial health outcomes (30). However, this result was not maintained at the long-term follow-up, one year after the end of the intervention, although, the longitudinal analysis excluding the 9 month data indicated potential effects also at 15 months. The absence of long-term effects may be disappointing, but not surprising, and is consistent with other studies (148, 149). Like any other type of training, balance exercises are most effective when they are regularly performed and the positive effects decline over time if training is not maintained. Physical activity is a complex behavior, and to accomplish a sustained change, a prolonged intervention may be required. To reinforce the intervention with more support regarding habitual physical activity, such as personalized behavior change counselling or physical activity on prescription are other possible ways to help participants maintain a healthy behavior.

We could not find that an increase in steps per day was mediated by improvements in HRQoL, gait speed, balance performance or falls self-efficacy as presumed (Figure 5). It is plausible that a larger sample is needed to detect these types of associations. Liu-Ambrose and colleagues (150) reported comparable findings in a study including 98 older women with low bone mass, which demonstrates the complexity of these correlations.

It is encouraging that the intervention had an impact on habitual physical activity, even though it did not contain any specific components to support the participants to increase their activity level. As indicated by the results from Study I and Study IV, many of the participants were physically active and had a positive attitude to physical activity, and the social interaction between participants during the group training sessions may have stimulated the least active participants to become more active independent of effects of the balance-training. Social support and positive role models can help to adopt health behaviors and increase physical activity self-efficacy (113). In addition, there is always a possibility that other factors that were not assessed in this study contributed to the result, for example improved aerobic fitness or increased muscle strength.

5.2.2 Qualitative findings

Many factors influence how physical activity is performed: how often, which type of activity, in which setting, at which intensity level, and last, but not least, for which reasons. No research method can provide fully valid and reliable data for all dimensions, and studies with different approaches are needed to obtain a more complete picture. Qualitative methods can provide insight into the individual's perspectives and explore experiences and perceptions that cannot be elicited through quantitative methods. Study IV contributed to valuable complementary findings to answer the overall research aim.

Even though the women were well aware of their osteoporosis diagnosis and many had a history of fractures, most of them perceived themselves as being healthy. By taking necessary precautions in their everyday life, such as avoiding lifting heavy items or being extra careful when walking on uneven or slippery surfaces, they had adapted successfully to a life with a fragile body and could continue to be active and achieve a healthy number of steps per day. Some women described how they had added physical activity routines after being diagnosed with osteoporosis, which gave them a sense of control over their bone health.

A central part of patient empowerment is to enhance the patients' capacity to make decisions about their health behavior, and strengthening a person's exercise self-efficacy is one way to accomplish that. Women who had participated in the balance-training program declared how the specific training had contributed to strengthen their physical activity confidence, which gave them a sense of mastery.

Obviously, being aware of potential fall-risks is especially important for persons with osteoporosis, and fracture prevention is essential, given the high risk of fracture related morbidity and even mortality (71, 73). However, it was significant how the information about physical activity in relation to osteoporosis given by physicians was either lacking or focused on activity restrictions. This was perceived as confusing and discouraging. One woman even described how the information about her brittle bones given by her physician scared her so much that she did not dare to do any kind of physical activity for a long period. This highlights the importance of giving clear and correct advice, and recognizing the patient's understanding and interpretation of the risks and benefits of physical activity. Health care professionals working with patients with osteoporosis should emphasize that osteoporosis is not a reason to avoid physical activity. On the contrary, explicit advice encouraging appropriate physical activity and exercise should be given, and especially weight-bearing activity should be stressed.

Many informants expressed a wish to be seen as an individual by their caregivers. This wish included getting individualized advice and treatment. Physical therapists can give disease-specific advice and tailor physical activity and exercises programs to the individual's needs and preferences. A close and trustful relationship with health care professionals and continued follow-up are important factors for osteoporosis patients (151), and our findings suggest that many women can manage to be active on their own if they feel secure about how much stress their bones can endure and which exercises are safe and suitable.

5.3 HEALTH-RELATED QUALITY OF LIFE

In the cross-sectional analysis in Study I, we found associations between physical activity level and physical function components of SF-36, but not with general health or vitality, as might be expected. Low Active participants had lower mean score in all domains compared to Active, but this was partly due to a higher mean age, and the between-group differences were attenuated in the age-adjusted logistic regression. Previous research has found lowered HRQoL in all domains after fractures, especially hip and multiple vertebral fractures, but two

years later HRQoL was improved again after all types of fractures (152). In our sample, 40 percent had not experienced a fracture the last 10 years, which may partly explain our results. Associations between daily steps and mental health has previously been found in older adults, but at steps per day levels lower than recorded by most of our participants, <4,000 steps per day (34).

Interestingly, we found that participants 75 years and over presented higher mean scores in all SF-36 domains, except for bodily pain and role emotion (Figure 10), compared to an age and gender matched Swedish normative sample (153). This is contradictory to findings in other studies, suggesting a lower HRQoL in patients with osteoporosis, both with and without vertebral fractures, compared with healthy controls (81-83). A potential explanation is the design of the intervention, training sessions three days per week for 12 weeks, which may be perceived as too much for the oldest persons with osteoporosis. This may have biased the sample by attracting individuals healthier than average in the age-span over 75 years. Younger participants, 65-74 years, were more similar to osteoporosis samples in other studies, scoring lower HRQoL than normal in all domains.

We hypothesized that participating in the balance-training would improve HRQoL through improved functional status and general health perceptions, and subsequently overall quality of life, as described in the conceptual model of HRQoL (Figure 4). Contrary to our expectations, the analysis of Study III did not find any effects of the balance-training intervention on HRQoL, despite observed improvements in fall-related concerns and physical function (4). It is possible that the absence of effects was related to lack of power. Even though we found cross-sectional associations between daily steps and HRQoL in Study I, treatment effects might be harder to verify and need larger samples (80). Due to the structure of the SF-36 instrument — with frequently skewed data in some of the domains — has the preferred sample-size been proposed to be larger than in our study; although, it has also been suggested that group sizes of 25 participants could be sufficient (154). Another potential explanation is that a longer intervention is needed to detect improvements in HRQoL. Madureira and colleagues (155) found that a 40-week long intervention, including physical therapist supervised balance-training once a week and home-based exercises three times a week, improved HRQoL in a group of older women with osteoporosis.

It is essential to use PROMs, such as HRQoL, in evidence based practice, both in clinical and research evaluations (63). PROMs capture patients' own experiences of the impact of their condition, and its treatment, on their life (63). PROMs can assist physiotherapists in their clinical reasoning process for diagnosis and treatment, with a specific focus on the patient's perspective. We choose SF-36 to assess HRQoL, which is a global instrument. Condition-specific PROMs tend to be more responsive to subtle changes in the patient's condition (63) and an osteoporosis-specific instrument could potentially have generated a different result. However, a major advantage with SF-36 is that it is widely used, which facilitates comparisons with other studies. It is also found to be valid and reliable for the general Swedish population (66, 122), with available normative values for older adults (153).

Qualitative research methods are valuable to study issues in depth and detail and can be an alternative when studying concepts such as quality of life (51). Even though the aim of Study IV was to describe perceptions and experiences of physical activity, it also provided information about subjective well-being and quality of life, especially related to physical activity. The women described how physical activity was connected to positive emotions: mental and physical well-being and feelings of mastery. Several women mentioned that the balance-training had positive impact on their self-efficacy, thereby influencing overall quality of life.

5.4 Pedometer and Accelerometer Derived Steps

Pedometers and accelerometers are both useful tools for objective assessment of physical activity in research as well as in clinical interventions, and it is important to evaluate the feasibility of these devices. The main finding in Study II was that there were no systematic differences between self-reported Yamax pedometer steps and Actigraph accelerometer-derived steps in the BETA-OP group. This indicates that the two instruments can be used interchangeably on a group level in older adults with osteoporosis. The same result has previously been shown in a study on a general older population (156).

In the BETA-PD group, the pedometer was found to systematically generate lower step count values than the accelerometer. A possible explanation is that the spring level mechanism in the Yamax did not detect all steps due to the altered gait pattern, typical for Parkinson's disease, slow shuffling steps with diminished vertical movement. Previous studies have found that movement sensors, both accelerometers and pedometers, from different manufacturers have a tendency to underestimate step counts, particularly at slow walking speeds and short walking distances, and in individuals with altered gait pattern (157, 158). Many participants in the BETA-PD group also had difficulties with handling the pedometer or remembering to write down number of steps. Altogether, our results indicate that the Actigraph should be preferred over the Yamax for the assessment of steps in individuals with Parkinson's disease.

It is important to recognize that the study was carried out in free-living conditions and that the true step counts are unknown. Consequently, it is not possible to determine which sensor was more accurate. It is also important to notice that the results of this study only apply to the two sensor models tested, other accelerometer and pedometer brands may generate a different outcome.

5.5 Methodological Considerations

5.5.1 External validity

Our study sample was highly skewed in gender distribution and may not represent the average population of older adults with osteoporosis. Although we did address both genders when recruiting participants, only two men were included in Study I, II and III, and in Study IV all informants were women. This implies that the results might only be true for women. The small proportion of men is shared with other osteoporosis research (84) and there are

several possible explanations for this. Low BMD is more prevalent in older women and more women than men are diagnosed with osteoporosis (71). Women perceive more fall-related concerns (90) and may, therefore, be more conscious about their balance and more interested in taking part in a balance-training intervention. It has been suggested that older men may not be willing to admit being afraid of falling or having balance problems (90).

As in any sample of convenience, recruitment tended to favor healthier persons, with a higher socioeconomic status (159). It is reasonable to think that women who actively had chosen to take part in a balance-training intervention may have a more positive attitude towards physical activity and be more well-informed about osteoporosis treatment than average older adults. This may have influenced the results in several ways. One of our inclusion criteria was the ability to walk indoors without aid; consequently, our sample did not have severe mobility limitations or disabilities. Attitudes, climate specific issues, cultural differences and structural differences in health care may limit some results in Study IV to be context specific and thereby limit the transferability to persons with other backgrounds. Nevertheless, the characteristics of the informants are in many ways representative for other countries in Scandinavia and northern Europe, therefore the results are probably applicable for community-dwelling older adults living in these areas.

5.5.2 Internal validity

In the quantitative studies, the measurements chosen are considered to be valid and reliable for assessment in older adults. However, the lack of associations between changes in physical activity level and changes in covariates in Study III may be due to the assessment methods used; it is possible that they may be too insensitive to capture small changes of importance or require a larger sample. The BETA-OP study was powered to detect differences in FES-I, but sample size was not calculated to test mediating effects. Our population of older adults with osteoporosis and increased risk of falling was a heterogeneous group in many ways and the wide ranges in several covariates influenced the statistical calculations and might have aggravated statistical significance.

Although objective assessments of physical activity have many advantages over self-reported subjective methods in terms of bias, they provide insight only into short periods of the participants' everyday life. Interpretations of the results are based on the assumption that the amount of activity recorded during the week of wearing the pedometer and the accelerometer reflects the participants' habitual physical activity. It is possible that some participants changed their behavior because of the knowledge of being studied, or due to a raised awareness of physical activity level from recording daily number of steps. Choice of wear-time algorithm to determine when the accelerometer actually is worn or not may also influence the accuracy of the data. Comparisons with the log sheet where the participants noted the wear time allowed us to choose the right algorithm to minimize misclassification.

We analyzed accelerometer counts only from the vertical axis, as we did not have access to tri-axial accelerometers for all assessments, and it is possible that use of data from all axes

could have influenced the findings. However, research is lacking on adequate cut-points for older adults with chronic conditions when analyzing physical activity intensity data from all three axes. Other sources of error, when using pedometers and hip-worn accelerometers are that the sensors do not register upper-body movements, swimming, or bicycling. However, it should be noted that walking is the most common type of physical activity among older adults (25), suggesting that the sensors can produce reliable data on general activity patterns. The compliance for wearing the sensors was high and we believe that our physical activity data are reliable.

There are inevitable some disadvantages with dichotomization of variables; some information are lost and power is reduced (160). Nevertheless, it simplifies both the interpretation and presentation of results. Given the healthy aging perspective of this thesis and the wide range of daily steps in our sample, we needed to find a way to analyze our data to make sense from a clinical view. Translations of minimal daily step recommendations, to include the recommended amounts of MVPA, has been suggested to be 7,100 steps per day for healthy older adults, and to 4,600 steps per day for the most sedentary older adults or individuals living with disability or chronic illness (25). We chose a minimum of 5,000 steps per day as a cutoff in Study I and III for ‘sufficient’ physical activity, since this is a level previously found to be associated with health benefits (30). Another cutoff could have been the median value at baseline, 6,080 steps per day (160), which may have generated slightly different results. Obviously, there is no absolute, true, minimum number of daily steps to guarantee health; health outcome-referenced values differ depending upon parameter measured, and an individualized daily step target would probably be the best choice. However, by choosing 5,000 steps as a cutoff, a value still close to the suggested minimum level for older adults with chronic conditions, comparisons with other studies were facilitated (160).

The researchers assessing outcomes were blinded to group allocation at baseline assessments, but could not remain blinded at follow-up for pragmatic reasons alone; the funding allowed only enough researchers to carry out recruitment, intervention, and follow-up simultaneously. To prevent bias, the test procedure followed a pre-designed protocol and there were always two test leaders present during the physical tests in order to ensure that the participants got the same standardized instructions and that the tests were performed in the same way. In addition, the main outcome in this thesis, habitual physical activity, was objectively assessed, which attenuates the risk of bias due to non-blinded researchers. The design of Study III, offering individuals in the control group the opportunity to participate in balance-training after the long-term follow-up rather than offering a ‘sham’ intervention, did not allow participants to be blinded to allocation. Still, this is a problem shared with all exercise intervention trials. The choice to offer participants randomized to controls the same balance-training after the end of the study was both for ethical reasons, and to increase the chance of retaining control participants though the whole study period.

A problem with a relatively large proportion of dropouts, as in Study III, is that it may introduce bias. We did an extensive exploration of the characteristics of the participants who withdrew from the study, and found that missing outcome data could be assumed to be ‘missing at random’ and there were no differences between dropouts in the interventions group compared to dropouts in the control group. By including baseline steps per day as a covariate in the regression models, we also effectively measured change in step-count over the 3 months, irrespective of the physical activity level of missing participants. The GEE-analysis computed to evaluate long-term effects does not require a balanced design (i.e., observations at all four measurements for each participant), which allows for maximum utilization of data from all 91 participants.

5.5.3 Trustworthiness

In qualitative research, the term trustworthiness is used to support the argument that the findings are ‘worth paying attention to’, corresponding to the terms validity and reliability in quantitative research (129). Trustworthiness is especially important when using inductive content analysis as categories or themes are created from the raw data without a theory-based categorization matrix. Trustworthiness can be further divided into credibility, dependability, conformability, and transferability (129). Credibility relates to truth-value, in other words whether analysis process is sufficiently described and if informants have been identified and described accurately.

Dependability refers to stability of data over time and in different conditions. Conformability refers to the objectivity regarding the data’s accuracy, relevance, or meaning, and is achieved by involving two or more researchers in the analysis process. Finally, transferability refers to the potential of findings to be generalized or transferred to other settings or groups.

The description of the informants and the transparency of the data collection and analysis process, including quotations from the interviews, allow the reader to judge the trustworthiness of our results. We believe that we have followed the criteria for trustworthiness as described by Elo and colleagues (129), but there is always a possibility that prior understanding could overshadow new meanings and hinder noticing everything in the data. Due to the large amount of data, there is also a risk that data could have been overlooked or misinterpreted.

6 CLINICAL IMPLICATIONS

The high proportion of sedentary time found among the participants implies that physical therapists and other health care professionals who meet older adults with osteoporosis, have important roles in promoting physical activity. Assessment of physical activity is necessary to identify sedentary individuals and we propose that objective methods should be used in clinical practice. Pedometers are evidence based instruments that provide a good picture of a person's habitual physical activity to a low cost. A level of <5,000 steps per day can be used to identify sedentary individuals at risk for functional decline or morbidity, and help to prioritize and target interventions for the individuals most at need. Another advantage is that step counting also may trigger behavior change and can be used for goal setting and motivation as a complement to exercise referrals or other types of interventions aiming to increase physical activity. Accelerometers provide more detailed information about physical activity levels and patterns, but also requires software and data processing, and may therefore, primarily be suitable in research. Although, based on the results from Study II, we also recommend the use of accelerometer for clinical evaluations in individuals with altered gait.

Physical therapy interventions designed to help patients with chronic conditions or disability to reduce sedentary time have a large potential and may produce even greater benefits than for people without disabilities, because of the magnitude of sedentary behavior in this population. Our specific and progressive balance-training program focusing on dual- and multi-task exercises has previously been found to be effective in reducing fall-related concerns and improving gait speed and physical function. We found that it also was effective in increasing habitual physical activity in the most sedentary participant. Altogether, this suggest that the balance-training can be an important intervention for keeping older adults over the disability threshold.

This balance-training program in now evaluated with good results, both in a healthy older population and in a population diagnosed with osteoporosis. We believe that this balance-training program has potential to be successfully implemented in primary care physical therapy clinics. Additional individual support, such as behavioral change counseling, individual training or physical activity on prescription, may be needed to accomplish a sustained increased physical activity level in the most sedentary individuals. As exercise specialists, physical therapists can analyze and provide tailored advice and exercise programs, which is especially important for persons with osteoporosis.

It is important to identify older adults who may be at risk for falls and fractures and thereby reduce the risk of functional decline and premature mortality. Assessment of fear of falling or falls self-efficacy are useful for identifying older adults with an increased risk of falling; however, our findings show that a high FES-I score is not useful for identifying individuals with low activity levels. Gait speed or physical function assessments seem to be more relevant for detecting persons at risk for a sedentary behavior. The associations with the physical subscales of SF-36 confirm the importance of retaining physical fitness and a lower

extremity function in old ages in order to be able to remain physically active, in addition strength training should probably be recommended as a complement to the balance-training.

These results provide an understanding of the challenges of being physically active for older women with osteoporosis and highlight the need to consider the individual's concerns and knowledge regarding physical activity and bone health. Our findings may be useful when planning osteoporosis management programs and for health-promotion interventions.

7 FUTURE DIRECTIONS AND RESEARCH

Increased physical activity at 3 months is a significant finding, but maintenance of change is of key importance. This could be further studied when implementing the balance-training program in primary health care clinics and community settings. Additional strategies to support physical activity, such as behavioral change counseling and exercise referrals, may be useful supplements to the program, and should be investigated. It would also be interesting to evaluate if initiatives to encourage participants to continue to be physically active together after the program, such as walking groups, could be of value.

Another future research area of importance is to study how the program can be implemented in a clinical setting. Which adaptations that might be necessary to make; if or how the program will be influenced by the clinical context; and what kind of support is needed, such as materials, educational support, and coaching or guidance to physical therapist clinicians.

For a healthy aging, efforts must be made to reach those older adults who do not succeed in being active on their own, and interventions focusing on alternative physical activity promotion for older adults should be further developed and evaluated. Simple instructions on television or online may be possible ways to reach sedentary older adults who do not have the possibility or wish to walk for exercise or attend training centers or physical therapy clinics.

As the most current accelerometers are tri-axial, future studies should investigate the advantage of using all three axes when studying older adults with osteoporosis or other chronic conditions, as slow walking speed and altered gait pattern may influence the accuracy of the assessment.

Furthermore, future studies should explore the information given to patients with osteoporosis, with a particular focus on physical activity advice, and how this is perceived and interpreted by the patients.

Finally, to verify our qualitative findings, more research is needed in other cultural and socioeconomic settings.

8 CONCLUSIONS

This thesis has shown that:

- A specific and progressive balance-training program with dual- and multi-task exercises was effective in increasing habitual physical activity in the most sedentary participants, however, to accomplish a sustained change a prolonged intervention or additional individual support may be needed.
- Many older adults with osteoporosis are highly sedentary and a large proportion does not reach health enhancing physical activity recommendations.
- A daily step level of <5,000 steps per day was associated with slower gait speed, poorer balance performance, lower HRQoL in physical function scales, and more time spent in sedentary behavior. This highlights the need to objectively measure physical activity, as steps per day can be used to identify sedentary individuals at risk for functional decline or morbidity.
- Fear of falling and falls self-efficacy were not associated with objectively assessed habitual physical activity. Regardless of fall-related concerns, many older adults with osteoporosis are physically active and walk for exercise.
- Both the Yamax LS2000 pedometer and the Actigraph GT1M/GT3X+ accelerometers can be used to assess steps per day in older adults with osteoporosis, but for individuals with altered gait pattern, such as persons with Parkinson's disease, accelerometers should be preferred.
- Lack of physical activity promotion and conflicting advice from physicians to older women with osteoporosis was perceived as confusing and this created uncertainty about the benefits of physical activity on bone health.
- Older women with osteoporosis who have a positive attitude to physical activity and knowledge of the possible health effect of exercise manage to be physically active on their own, which can contribute to physical and mental well-being.
- Encouragement and guidance from physical therapists, both individually and in group training, were perceived as very important by older women with osteoporosis; however, more individualized instructions regarding safe and suitable exercise was requested.

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